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CHANGE AND ITS CHALLENGE

Every generation enjoys the use of a vast hoard bequeathed to it by antiquity, and transmits that hoard augmented by fresh acquisitions to future ages.
—THOMAS B. MACAULAY.

ISN'T it strange how seldom any of us in this busy world pause to realize the vastness of our debt to our predecessors—or to appraise the legacy of new knowledge we hope to leave to succeeding generations? Chemical engineers, in particular, are prone to think that history holds little of practical value and interest. We are a new profession for which, as Dr. Little has aptly remarked, the "Book of Genesis is yet to be written." Our eyes are only for the present and the future. Our jobs are to recognize, interpret and apply the newest discoveries of science. Why should we waste time with the past, especially with the dim, distant days of alchemy and the crude chemistry and inefficient engineering of our forebears?

Such questions, occasionally prompted by the historical skeptics, may seem difficult to answer, yet a little reflection may possibly reveal a few plausible reasons for a backward look right now. We are in a period of stock-taking. One of the purposes behind the great celebration this month of American Chemical Industries Tercentenary is to bring home to the Nation our long record of achievement. Only when viewed from the perspective of history can we hope to establish the essential nature of our long-time contribution to modern civilization. Only on the basis of past performance in the custodianship of national responsibility can we expect to receive the support necessary for greater growth and development in the future.

Chemical engineers occupy a strategic position in these changing times and conditions. The advances have been so rapid that chemical engineering itself has, of necessity, changed tremendously in the relatively short time of its recognized existence. All the more reason, therefore, that we should look back at the prior art and trace the historical development of the unit operations and processes of chemical engineering. The slow progress from the crudest apparatus of the alchemist down to the most efficient equipment of today has made possible the present advance of our industries. More important and more practical, it shows the strength of the chemical engineer's position in the developments yet to come.

So in this issue of *Chem. & Met.* we have attempted to combine a historical look at the past with a present-day appraisal of trends and improvements in the tools of the profession. Subsequent issues will focus attention more specifically on developments that have occurred since the 1933 Award for Chemical Engineering Achievement. Before the year is over we hope again to have the privilege of presenting our compliments to that company in the process industries which, through the effective use of chemical engineering in any phase of its activity, has contributed most to the advance of the industry and profession. Chemical engineering achievements and developments are the answer to the challenge of change that now faces all of us.

CHRONOLOGY

Today's chemical engineering has its roots firmly implanted in yesterday's scientific achievements. + + Hence any review of significant dates for this one branch of engineering must necessarily overlap much of man's progress in other basic arts and sciences.

400 B.C. circ. Democritus gave quantitative form to atomic hypothesis
350 B.C. circ. Aristotle postulated a world ether
250 B.C. circ. Archimedes laid foundations of hydrostatics and mechanics
750 circ. Geber described "spirit of alum"
1250 circ. Albertus Magnus taught transmutability of elements
1250. Mechanical clock escapement developed
1425. Basil Valentine published "The Triumphal Car of Antimony"
1500 circ. Copernicus proclaimed heliocentric system of world
1556. Agricola published "De Re Metallica"
1597. Galileo invented thermometer
1600. Gilbert presented first important studies on magnetism
1608. Jamestown Colony produced pot or soap ashes for shipment to England
1609. Kepler presented laws of planetary motion
1620. Coal used for smelting iron ore
1635. Winthrop made survey of American chemical resources
1643. Torricelli discovered atmospheric pressure
1650 circ. Pascal made fundamental studies of hydrostatics and hydrodynamics
1662. Boyle presented law for perfect gases
1662. Royal Society founded in England
1665. Hooke published prophesy on artificial silk
1675. Romer calculated velocity of light
1680. Leeuwenhoek did his work on yeasts
1687. Newton presented laws of motion
1690. Huygens presented wave theory of light
1697. Stahl advanced phlogiston theory
1700 circ. Gray defined difference between conductors and non-conductors of electricity
1705. Newcomen constructed his steam engine
1714. Fahrenheit invented his thermometer scale
1755. Fuming sulphuric acid made at Nordhausen
1769. Watt patented his steam engine
1772. Lavoisier presented theory of combustion
1774. Priestley discovered oxygen
1775. Galvani discovered "animal electricity"
1778. Baumé described his scale for hydrometers
1783. Cavendish made water by burning hydrogen
1784. Scheele discovered chlorine
1785. Coulomb presented law of electric force
1790. LeBlanc developed his soda process
1792. Chemical Society of Philadelphia founded
1793. Harrison made sulphuric acid in U. S. A.
1798. Tennant patented process for making chlorate of lime
1800 circ. Dalton formulated atomic theory
1800. Rumford presented kinetic theory of heat
1800. Volta made first electric battery
1801. E. I. duPont de Nemours & Co. founded
1806. Coal gas for lighting first made in U. S. A.
1807. Davy made sodium and potassium
1808. Gay-Lussac presented law of multiple volumes
1810. Continuous chamber process for sulphuric acid perfected
1811. Avogadro formulated his law of molecular volumes
1817. Fraunhofer discovered lines in solar spectrum
1818. Berzelius introduced new chemical nomenclature and revised weights of combination
1819. Dulong and Petit discovered law of atomic heat
1820. Oersted discovered electromagnetism
1821. Seebeck discovered thermoelectric currents
1824. Carnot developed science of thermodynamics
1824. Liebig completed study of fulminates
1827. Wöhler produced aluminum
1827. Gay-Lussac installed tower at Chauncy to absorb chamber-plant end gases
1829. Henry made the first electromagnet
1830. Kuhlmann discovered use of platinum catalyst in ammonia oxidation
1831. Faraday discovered electromagnetic induction
1831. Peregrine Phillips patented essential details of contact process for sulphuric acid
1831. Chloroform discovered by Guthrie
1834. Faraday formulated electrochemical laws
1836. Daniel invented chemical battery
1836. Elkington developed electroplating
1836. J. C. Booth of Philadelphia founded oldest firm of consulting chemical engineers
1839. First Grasselli plant built in Cincinnati
1839. Goodyear patented process for vulcanizing rubber
1840. Liebig published work on organic chemistry in agriculture and physiology
1841. Bunsen invented carbon-zinc battery
1845. Petroleum discovered in Pennsylvania
1846. Gun cotton made by Schönbein
1847. Collodion made in U. S. A. by Maynard
1850. First fertilizer plant built in U. S. A.
1853. Watt and Burgess invented soda pulp process
1856. Perkin discovered mauve—first coal-tar dye
1856. Bessemer developed process for steel making
1857 Bunsen published work on gas analysis
1857 Société Chimique de France founded
1858. Hofmann prepared rosaniline
1859. First petroleum refinery built in Pennsylvania

CHRONOLOGY

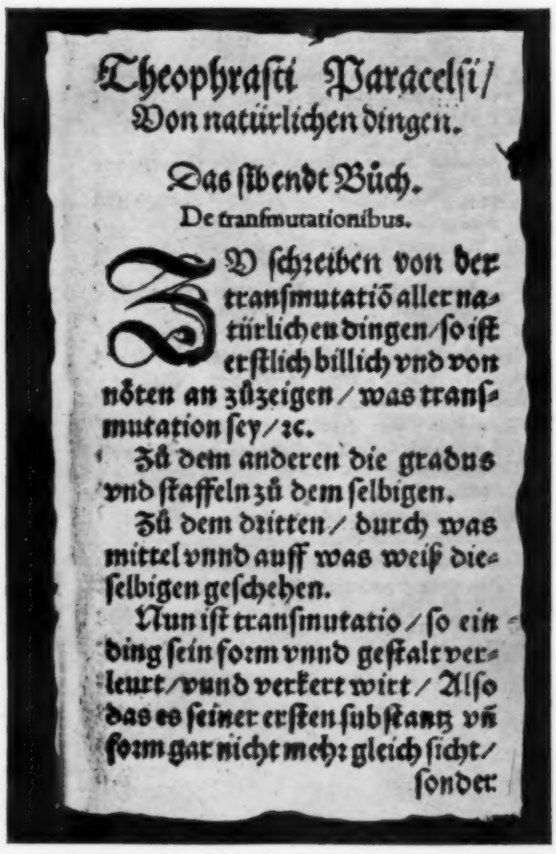
1859. Bunsen and Kirchhoff developed spectral analysis
1859. Kirchhoff introduced concept of black-body radiation
1859. Planté invented lead storage cell
1859. First Glover tower built
1865. Solvay developed ammonia soda process
1865. Kekulé advanced ring theory for benzene
1867. Tilghman invented sulphite pulp process
1867. Deutsche Chemische Gesellschaft founded
1868. Pasteur studied acetic acid fermentation
1868. Leclanché invented dry cell
1869. Mendelejeff presented his periodic system
1869. Perkin and Caro, Graebe and Liebermann made alizarine from anthraquinone
1869. Hyatt first made celluloid in Albany, N. Y.
1872. Electrolytic copper refining started in U. S. A.
1873. Maxwell presented his theory of electricity and magnetism
1875. Gibbs formulated his phase rule
1876. American Chemical Society founded
1878. Institute of Chemistry of Great Britain founded; obtained Royal charter in 1885
1880. Synthetic indigo made by Baeyer
1882. Edison invented incandescent lamp
1882-3. DeLaval and Parsons introduced basic steam turbine types
1884. First American Solvay plant built
1886. Hall produced electrolytic aluminum
1886. Van't Hoff showed analogy between gases and dilute solutions
1886. Mond developed carbonyl process for refining of nickel
1887. Arrhenius formulated theory for electrolytic dissociation
1888. Herz discovered electromagnetic waves
1888. Willson started commercial production of carbide
1889. First commercial application of cyanide process in gold metallurgy
1890. Castner introduced electrolytic alkali production
1890. Acheson made silicon carbide in electric furnace
1891. Frasch developed his process for sulphur mining
1891. Chardonnet started artificial silk factory at Besancon
1892. LeSueur invented diaphragm-type electrolytic chlorine cell
1894. Roentgen discovered x-rays
1894. Cross and Bevan developed viscose
1894. Power plants started at Niagara Falls
1896. Becquerel discovered radioactivity
1896. Acheson made graphite in electric furnace
1897. Large-scale indigo production in Germany
1897. Thomson showed electric and magnetic deflection of cathode rays
1897. Sabatier developed hydrogenation process
1898. Madame Curie discovered radium
1898. Contact processes for sulphuric acid patented
1898. Bleaching powder made by Dow, from electrolytic chlorine
1900. Planck presented his quantum theory
1900. Heroult started smelting of steel in electric furnace
1900. Edison developed nickel storage battery
1900. Ostwald patented ammonia oxidation
1901. First American contact plant built
1902. Electrochemical Society founded
1903. Birkeland and Eyde started nitrogen fixation plant in Norway
1904. Cottrell invented electrostatic precipitation
1904. Betts refined lead electrolytically
1905. Frank and Caro developed cyanamide process
1905. Becket produced pure ferro alloys by silicon reduction
1906. DeForest invented radio tube detector
1906. Hybinette developed electrolytic process for refining of nickel
1908. American Institute of Chemical Engineers founded
1908. Goldschmidt developed thermite process
1908. Baekeland announced new molding plastic
1909. Bradley and Lovejoy demonstrated feasibility of nitrogen fixation at Niagara Falls
1911. Cellulose acetate silk made by Dreyfus
1912. Brearley developed stainless steels
1912. First Burton cracking still started
1913. Haber perfected his ammonia process
1913. Moseley arranged elements by atomic numbers
1913. Coolidge invented filament x-ray tube
1913. Rutherford and Bohr presented atom model
1914. Pyrex glass introduced
1914. Steam solvent process used for manufacture of naval stores
1915. Langmuir produced tungsten filaments
1915. Clark began studies on pH concentration
1915. McAfee introduced aluminum chloride in petroleum refining
1915. Weizmann studied production of acetone and butyl alcohol
1916. Commercial production of artificial leather became important
1919. Northrup introduced high-frequency induction furnace
1919. Sperry produced electrolytic white lead
1920. Phosphoric acid produced by electric furnace smelting
1920. Sodium produced by electrolysis of sodium chloride in Downs cell
1922. Fink developed chromium plating
1922. Sheppard and Eberlein electrodeposited rubber
1923. American Institute of Chemists founded
1923. Tetra ethyl lead introduced as anti-knock compound
1925. Ethylene glycol and related solvents made from petroleum
1925. Langmuir invented atomic hydrogen welding
1927. Contact acid made with vanadium catalyst
1930. Vinylite resins made from acetylene
1930. Production of synthetic ethanol started
1930. Iodine recovered from California brines
1930. Plant for hydrogenation of petroleum started at Bayway, N. J.
1933. Synthetic rubber produced commercially from acetylene
1933. Urey discovered "heavy water"
1934. Bromine extracted commercially from sea water at Cape Fear, N. C.

When Did Chemical Engineering First Have Its "Day in the Sun"?

This interesting old title page from Herr Lazari Erckers' problem book of 1673 (now the property of A. E. Marshall) gave Old Sol a label we can't quite translate but reading from left to right we find that those mountain peaks bear the alchemical symbols of gold, copper, iron, lead, tin, mercury and silver.

How old is Anne? Which came first, the chicken or the egg? Who was the first chemical engineer? And why? These are some of the puzzlers with which this amateur historian concerns himself. Anne, for the purpose of his discussion, is the fair goddess that directs the professional destinies of all good chemical engineers. Chemical engineering, he assumes, is the old hen-mother of us all and, as for the eggs, some chemical engineers are good, some bad—and all of them likely to hatch out into almost anything any time!—EDITOR.

SOME CHEMICAL ENGINEERING


Theophraſti Paracelſi/
Von natürlichen dingen.

Das ſibendt Büch.

De tranſmutationibus.

DV ſchreiben von der tranſmutatiõ aller natürlichen dingen/ſo iſt erſtlich billich vnd von nöten an zůzeigen/ was tranſmutation ſey/ ꝛc.

Zů dem anderen die gradus vnd ſtaffeln zů dem ſelbigen.

Zů dem dritten/ durch was mittel vnnd auff was weiß dieſelbigen geſchehen.

Nun iſt tranſmutatio/ ſo ein ding ſein form vnnd geſtalt verleurt/vnnd verkert wirt/ Alſo das es ſeiner erſten ſubſtantz vñ form gar nicht mehr gleich ſicht/ ſonder

to keep his life in constant turmoil. With it all, Paracelsus was a most prolific writer for no less than 234 publications are ascribed to him, dealing not only with alchemy and medicine but with astrology, black magic, and even theology. I like particularly what he had to say about his alchemistic brothers for his words remind me so much of certain chemical engineers of my acquaintance:

> THEY do not give themselves up to ease and idleness, strutting about with haughty gait, dressed in silk, with rings ostentatiously displayed on their fingers, or silver poignards fixed on their loins and sleek gloves on their hands. But they devote themselves diligently to their labors, sweating whole nights and days over fiery furnaces. They do not kill time with empty talk but find delight in their laboratory. They are clad in leathern garments, and wear a girdle to wipe their hands upon. They put their fingers among the coal, the lute and the dung, not into gold rings. Like blacksmiths and coal merchants, they are sooty and dirty, and do not look proudly with sleek countenance. They perceive that the work should glorify the workman, not the workman the work. Passing by all these vanities, therefore, they rejoice to be occupied at the fire and to learn the steps of alchemical knowledge. Of this class are: Distillation, Resolution, Putrefaction, Extraction, Calcination, Reverberation, Sublimation, Fixation, Separation, Reduction, Coagulation, Tincture and the like.

Note particularly this reference to "steps of alchemical knowledge." One is reminded strangely of certain "unit operations of chemical engineering." Yet there seems to be thoroughly convincing evidence [see A. H. White, *Trans. A.I.Ch.E.*, vol. 21, p. 55 (1928) and A. D. Little, *Silver Anniversary Volume, A.I.Ch.E.*, p. 7 (1933),] that this present-day concept of chemical engineering first appeared in a report made by Dr. Arthur D. Little to the Corporation of the Massachusetts Institute of Technology in December, 1915, and subsequently led to the foundation of the School of Chemical Engineering Practice at that institution. The appearance in 1923 of Walker, Lewis and McAdams' "Principles of Chemical Engineering," gave us the first comprehensive, quantitative treatment of the unit operations. Their wide acceptance on the part of the profession has come about only during the past dozen years.

But getting back again to Paracelsus, 400 years ago, he published in 1527 a little book called "von natürlichen Dingen" of which the seventh book or chapter was entitled "de Transmutationibus." Professor Badger has supplied me with photographs of the opening pages of this chapter, as well as the literal translation that appears below on this page. Note how carefully the alchemist describes the ordinary chemical engineering processes (transmutations) and the chemical engineering unit operations (steps or degrees of transmutation). Of the latter he then had but seven, and seven only.

Skipping another 100 years and across the Channel to England, we find that one of the unit operations has had a whole treatise written about it. John French's

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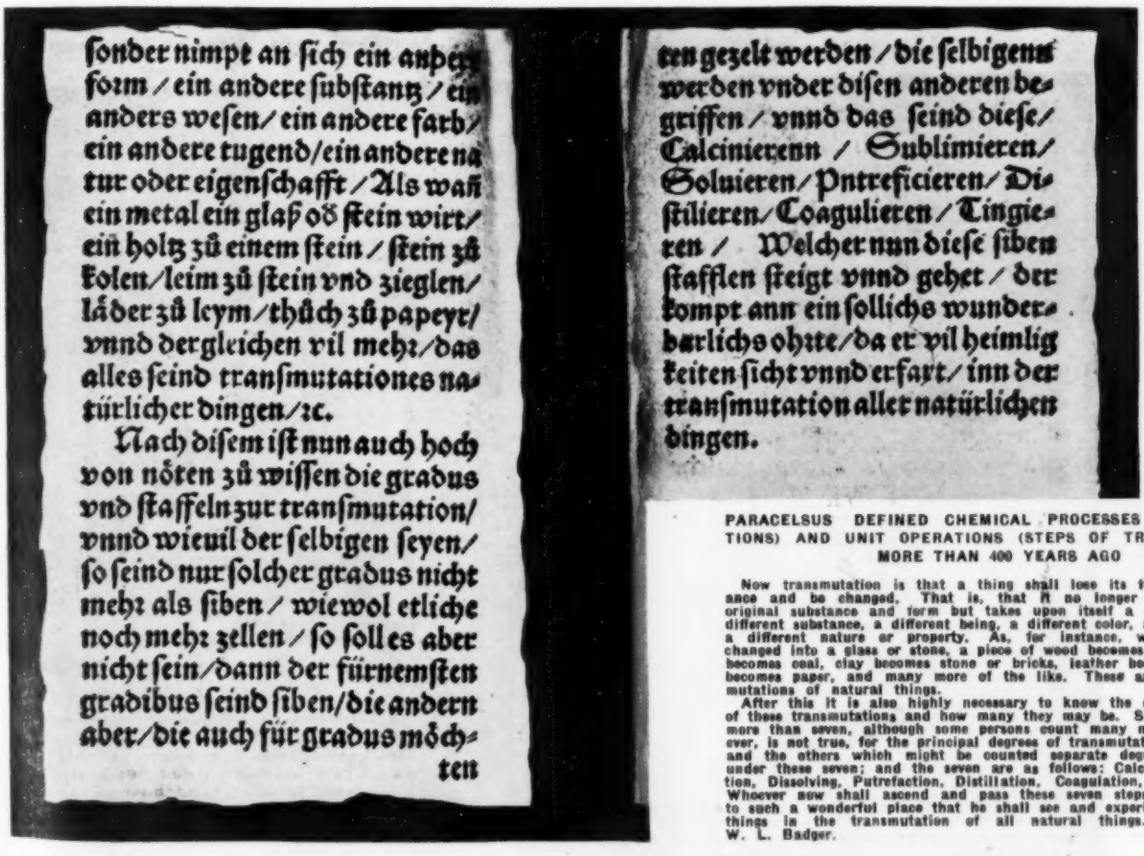
BEGINNINGS



ſonder nimpt an ſich ein anders form / ein andere ſubſtantz / ein anders weſen / ein andere farb / ein andere tugend / ein andere natur oder eigenſchafft / Als wañ ein metal ein glaß oð ſtein wirt / eiñ holtz zů einem ſtein / ſtein zů kolen / leim zů ſtein vnd zieglen / läder zů leym / thůch zů papeyr / vnnd dergleichen vil mehr / das alles ſeind tranſmutationes natürlicher dingen / ꝛc.

Nach diſem iſt nun auch hoch von nöten zů wiſſen die gradus vnd ſtaffeln zur tranſmutation / vnnd wieuil der ſelbigen ſeyen / ſo ſeind nur ſolcher gradus nicht mehr als ſiben / wiewol etliche noch mehr zellen / ſo ſoll es aber nicht ſein / dann der fürnemſten gradibus ſeind ſiben / die andern aber / die auch für gradus möchten

ten gezelt werden / die ſelbigenn werden vnder diſen anderen begriffen / vnnd das ſeind dieſe / Calcinierenn / Sublimieren / Soluieren / Pntreficieren / Diſtilieren / Coagulieren / Tingieren / Welcher nun dieſe ſiben ſtafflen ſteigt vnnd gehet / der kompt ann ein ſollichs wunderbarlichs ohrte / da er vil heimligkeiten ſicht vnnd erfart / inn der tranſmutation aller natürlichen dingen.

PARACELSUS DEFINED CHEMICAL PROCESSES (TRANSMUTATIONS) AND UNIT OPERATIONS (STEPS OF TRANSMUTATION) MORE THAN 400 YEARS AGO

Now transmutation is that a thing shall lose its form and appearance and be changed. That is, that it no longer appears like its original substance and form but takes upon itself a different form, a different substance, a different being, a different color, a different power, a different nature or property. As, for instance, when a metal is changed into a glass or stone, a piece of wood becomes a stone, a stone becomes coal, clay becomes stone or bricks, leather becomes glue, cloth becomes paper, and many more of the like. These are all the transmutations of natural things.

After this it is also highly necessary to know the degrees and steps of these transmutations and how many they may be. Such steps are not more than seven, although some persons count many more. This, however, is not true, for the principal degrees of transmutation are but seven and the others which might be counted separate degrees are included under these seven; and the seven are as follows: Calcination, Sublimation, Dissolving, Putrefaction, Distillation, Coagulation, and Coloration. Whoever now shall ascend and pass these seven steps, he shall come to such a wonderful place that he shall see and experience many secret things in the transmutation of all natural things.—Translated by W. L. Badger.

"The Art of Distillation" published in London in 1651 is a most comprehensive book. From a first edition kindly loaned me by President Albert E. Marshall, A.I.Ch.E. official delegate to the Engineering Societies' Joint Committee on the History of Engineering, I have photographed the frontispiece and a group of interesting pages. Here under the guise of a glossary of "hard words" and "tearms of art," we find listed a half hundred unit operations rivaling in variety if not in scope *Chem. & Met.'s* classification presented last May by my editorial colleague, T. R. Olive. Perhaps when we get right down to the last analysis, there isn't so much new after all in our unit-process-unit-operation concept.

When Did the Profession Develop?

This much of "alchemical engineering" considerably anteceded industrial chemistry which, according to Dr. Little, had its beginning in the modern sense about the time of the French Revolution with Le Blanc's discovery in 1790 of his process for making soda from common salt. Yet it was nearly 100 years more before chemical engineering became even dimly recognized as a distinct profession.

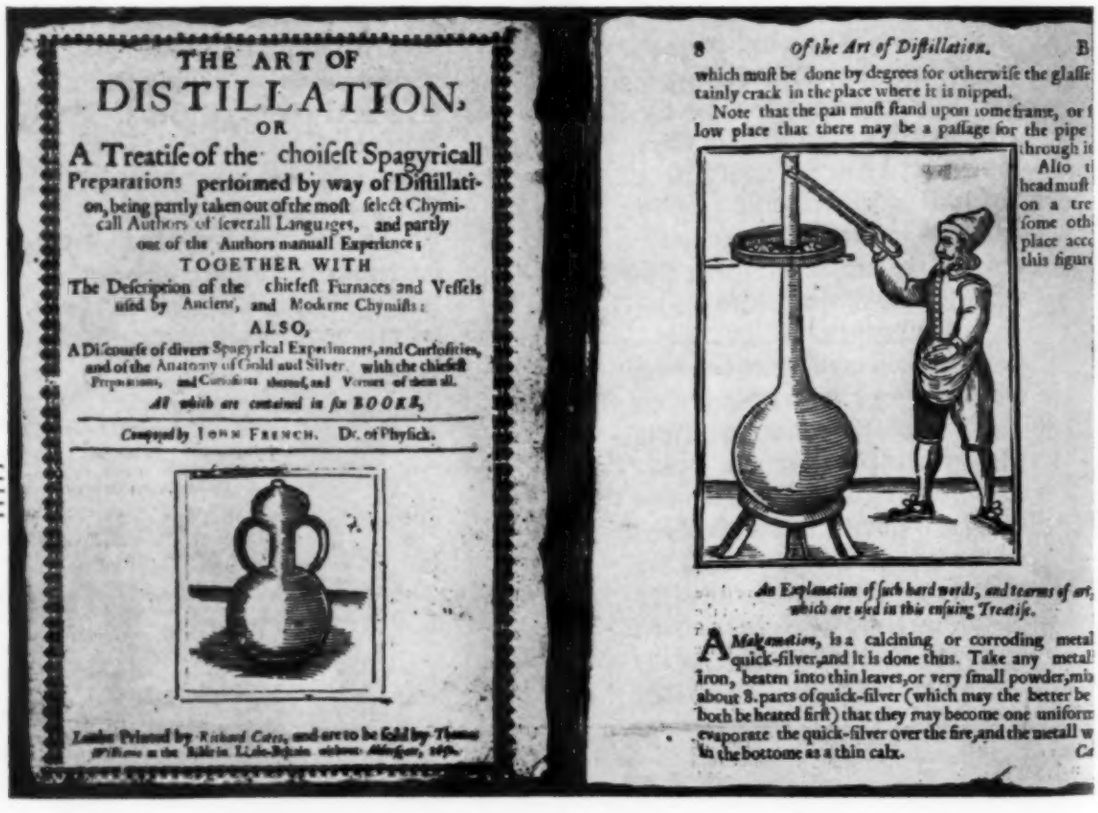
As far as I have been able to learn, the first attempt to bring chemical engineers together to form a national organization, took place in England about 55 years ago. Late in the Fall of 1879 a group of men headed by Professors Roscoe and Thorpe, E. K. Muspratt, J. Hargreaves, Ludwig Mond and George E. Davis, began a series of meetings in Liverpool, Manchester, and Widnes to consider the formation of "a society to promote the application of chemical science to manufacture, and the acquisition of that species of knowledge which constitutes the profession of a chemical engineer." And to show that they really knew what they meant, they defined a chemical engineer as follows:

> A CHEMICAL engineer is a person who possesses chemical and mechanical knowledge and who applies that knowledge to the utilization on a manufacturing scale of chemical action.

That definition, I submit, is just about as good today as it was 55 years ago. But, unfortunately, despite their good definition and intention, they fell into a controversy over the difference between an industrial chemist and a chemical engineer—a quarrel sadly reminiscent of many that have occurred in this country, even during the past few years. All this started with an editorial by Sir William Crookes, editor of *The Chemical News*. In the May 28, 1880 issue of that publication, he proposed that the new association should be known as "The Society of Technical Chemists" because he was afraid that the term "chemical engineer" might admit men "who are not chemists at all." Apparently some of his readers disagreed and it was not surprising to find in the very next issue (June 4, 1880, p. 261) two letters of protest addressed to the editor. One was from Eustace Carey of Gaskell, Deacon & Co., who later was to be one of the important founders of the Society of Chemical Industry. He concluded his letter with this significant statement: "To omit chemistry from the equipment of a chemical engineer seems to me an old simile—like the play of *Hamlet* with Hamlet left out."

The other letter was from George E. Davis, who had served as "honorary secretary pro tem" for the pre-organization meeting and who 20 years later was to write the first comprehensive "Handbook of Chemical Engineering" (published by Davis Bros. in London, 1901). Referring to the pre-organization meeting at Manchester, he wrote in part as follows:

This British exposition of one of the most important of shows how Paracelsus' seven "Steps of Transmutation"



THE ART OF
DISTILLATION,
OR
A Treatise of the choiſeſt Spagyricall Preparations performed by way of Diſtillation, being partly taken out of the moſt ſelect Chymicall Authors of ſeverall Languages, and partly out of the Authors manuall Experience;
TOGETHER WITH
The Deſcription of the chiefeſt Furnaces and Veſſels uſed by Ancient, and Moderne Chymiſts:
ALSO,
A Diſcourſe of divers Spagyrical Experiments, and Curioſities, and of the Anatomy of Gold and Silver. with the chiefeſt Preparations, and Curioſities thereof, and Vertues of them all.
All which are contained in ſix BOOKS,
Compoſed by JOHN FRENCH. Dr. of Phyſick.

London Printed by Richard Cotes, and are to be ſold by Thomas Williams at the Bible in Little-Britain without Aldersgate, 1651.

8 *Of the Art of Diſtillation.* B

which muſt be done by degrees for otherwiſe the glaſſe
tainly crack in the place where it is nipped.
Note that the pan muſt ſtand upon ſome frame, or
low place that there may be a paſſage for the pipe
through it
Alſo t
head muſt
on a tre
ſome oth
place acc
this figur

An Explanation of ſuch hard words, and tearms of art, which are uſed in this enſuing Treatiſe.

A *Melanation*, is a calcining or corroding metal
quick-ſilver, and it is done thus. Take any metal
Iron, beaten into thin leaves, or very ſmall powder, mi
about 3. parts of quick-ſilver (which may the better be
both be heated firſt) that they may become one uniform
evaporate the quick-ſilver over the fire, and the metall w
in the bottome as a thin calx.

THERE were many present who considered it advisable to form a Society of Chemical Engineers, though a great many were in favor of calling such a society "The Society of Technical Chemists." However, the majority were fairly agreed that not mere chemists were meant, but chemists with a thorough knowledge of physics combined with a fair knowledge of mechanics. Such men are not plentiful, we know, but they would, by forming such a society, help to diffuse that knowledge through the next generation, if not in the present. In the existing state of chemical industry the need of competent men to advise is becoming more and more felt. * * * Many processes can be carried along very successfully by chemists in laboratories but how few are able to make a chemical process go on a large scale, and simply because they have a lack of physical and mechanical knowledge combined with their chemistry.

I am not one of those who believe that our advisers in these great matters of chemical industry should be merely thorough engineers with a smattering of chemistry, but rather that chemistry should form the central pillar and be propped up by all the collateral sciences. A little chemistry is a dangerous thing, and if we start a new society with men who have a thoroughly sound chemical basis, and who have also founded their experience upon the fundamental principles of mechanics, the elements of mechanism and machine construction, I am sure we should be doing much to drive out rule-of-thumb, and with it most of the quaint, expensive and ofter futile machinery which unfortunately exists in too many works of the present day.

What came out of all this interest was, of course, the founding in June, 1881, of the Society of Chemical Industry with Professor Roscoe as its first president. In June, 1931, on the occasion of the fiftieth anniversary of its foundation, Stephen Miall, the brilliant editor of *Chemistry and Industry* wrote his most interesting "History of the British Chemical Industry," pointing out that it was many years before the Chemical Engineering Group was established within the Society. That group came into existence on Oct. 20, 1918. The Institution of Chemical Engineers, which, of course, developed independently, was formally incorporated on Dec. 21, 1922, and held its first annual corporate meeting June 8, 1923.

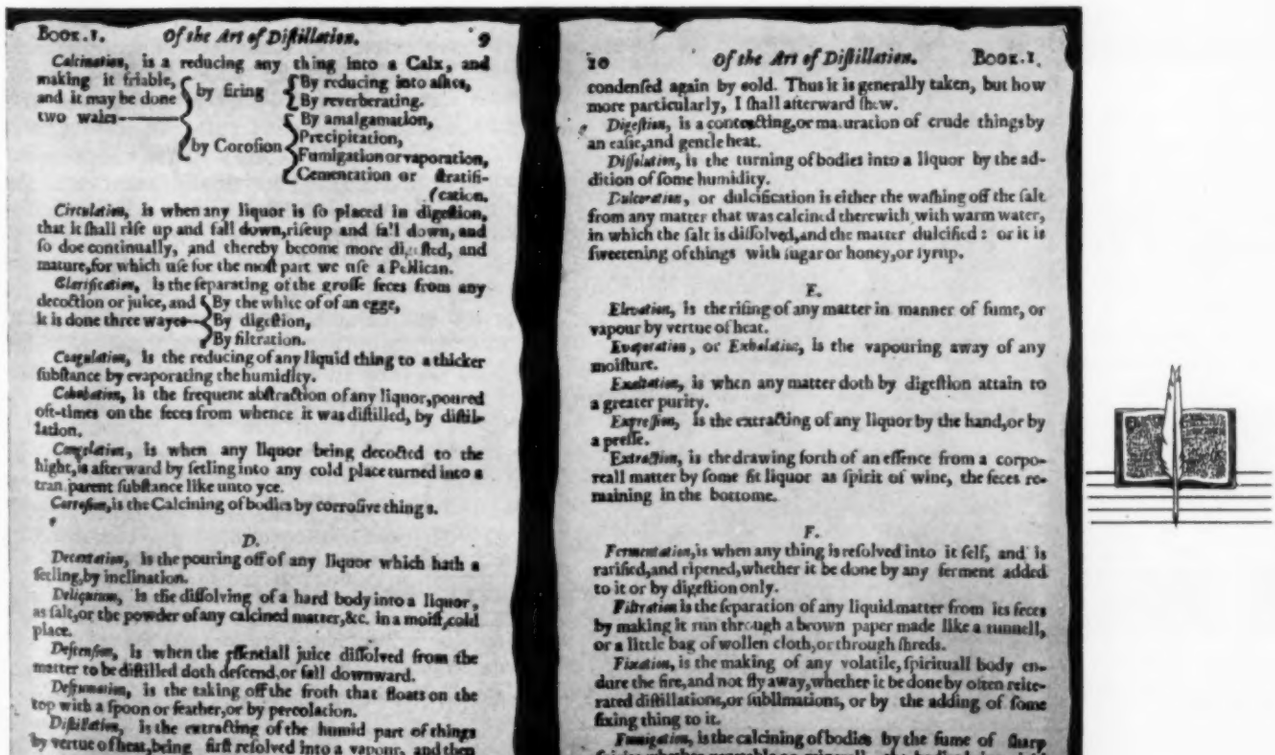
Leaving chemical engineering in England, let us pick up the thread of development in the United States. Here again we have a society being born in controversy. Here again we have an editor starting an argument that in the end led to the formation of the American Institute of Chemical Engineers.

The editor was Richard K. Meade, whose brave little publication, *The Chemical Engineer*, was just one year old when, in October, 1905, its editorial page propounded the question: "Why Not an American Society of Chemical Engineers?" The other branches of engineering already had strong national organizations in this country and Mr. Meade saw no reason why chemical engineers could not profit from a like association. He wrote:

> WE believe a society would greatly further the interests of the profession. Many plants intended for the manufacture of purely chemical products or to carry out chemical processes, are at the present time built by mechanical engineers. * * * The reason why most firms have employed mechanical engineers for this work is that they do not properly understand the significance of the profession of chemical engineering. They regard the chemist as a man of test tubes and beakers and "chemical engineer" as merely a high-sounding title some chemists have adopted. A national society of chemical engineers can do much to correct this impression and to properly advertise and advance the profession.

Not much happened, immediately at least, but Editor Meade kept on plugging. In March, 1907, he reprinted his original editorial and adopted an old journalistic trick of having reprints made and sending them out for criticism and comment accompanied by a personal letter to 50 or more leading chemists and chemical engineers of his acquaintance. He now found sufficient support

the unit operations included an interesting glossary that had grown to almost a half a hundred by 1651.



BOOK. I. *Of the Art of Diſtillation.* 9

Calcination, is a reducing any thing into a Calx, and making it friable, and it may be done two wayes— by firing (By reducing into aſhes, By reverberating.); by Coroſion (By amalgamation, Precipitation, Fumigation or vaporation, Cementation or ſtratification.)

Circulation, is when any liquor is ſo placed in digeſtion, that it ſhall riſe up and fall down, riſe up and fall down, and ſo doe continually, and thereby become more digeſted, and mature, for which uſe for the moſt part we uſe a Pelican.

Clarification, is the ſeparating of the groſſe feces from any decoction or juice, and it is done three wayes— By the white of of an egg, By digeſtion, By filtration.

Congelation, is the reducing of any liquid thing to a thicker ſubſtance by evaporating the humidity.

Cohobation, is the frequent abſtraction of any liquor, poured oft-times on the feces from whence it was diſtilled, by diſtillation.

Congelation, is when any liquor being decocted to the hight, is afterward by ſetling into any cold place turned into a tranſparent ſubſtance like unto yce.

Corroſion, is the Calcining of bodies by corroſive things.

D.

Decantation, is the pouring off of any liquor which hath a ſetling, by inclination.

Deliquium, is the diſſolving of a hard body into a liquor, as ſalt, or the powder of any calcined matter, &c. in a moiſt, cold place.

Deſcenſion, is when the eſſentiall juice diſſolved from the matter to be diſtilled doth deſcend, or fall downward.

Deſpumation, is the taking off the froth that floats on the top with a ſpoon or feather, or by percolation.

Diſtillation, is the extracting of the humid part of things by vertue of heat, being firſt reſolved into a vapour, and then

C Con-

10 *Of the Art of Diſtillation.* BOOK. I.

condenſed again by cold. Thus it is generally taken, but how more particularly, I ſhall afterward ſhew.

Digeſtion, is a contecting, or maturation of crude things by an eaſie, and gentle heat.

Diſſolation, is the turning of bodies into a liquor by the addition of ſome humidity.

Dulceration, or dulcification is either the waſhing off the ſalt from any matter that was calcined therewith, with warm water, in which the ſalt is diſſolved, and the matter dulcified: or it is ſweetening of things with ſugar or honey, or ſyrup.

E.

Elevation, is the riſing of any matter in manner of fume, or vapour by vertue of heat.

Evaporation, or *Exhalation*, is the vapouring away of any moiſture.

Exaltation, is when any matter doth by digeſtion attain to a greater purity.

Expreſſion, is the extracting of any liquor by the hand, or by a preſſe.

Extraction, is the drawing forth of an eſſence from a corporeall matter by ſome fit liquor as ſpirit of wine, the feces remaining in the bottome.

F.

Fermentation, is when any thing is reſolved into it ſelf, and is rarified, and ripened, whether it be done by any ferment added to it or by digeſtion only.

Filtration is the ſeparation of any liquid matter from its feces by making it run through a brown paper made like a tunnell, or a little bag of woollen cloth, or through ſhreds.

Fixation, is the making of any volatile, ſpirituall body endure the fire, and not fly away, whether it be done by often reiterated diſtillations, or ſublimations, or by the adding of ſome fixing thing to it.

Fumigation, is the calcining of bodies by the fume of ſharp ſpirits whether vegetable or minerall, the bodies being laid

over

for his proposal to warrant calling a meeting at Atlantic City during the 1907 convention of the American Society for Testing Materials. Included among the dozen or more who answered the call were such early leaders of the profession as William H. Walker, William Miller Booth, Samuel P. Sadtler, Arthur D. Little, John C. Olsen, H. P. Talbot, H. E. Diller, and E. C. Holton. From their extended discussion came the consensus that it might be desirable to form a new society—but, there was also the question: Could enough members be found to make the organization successful? They left it to a committee of six to study and report on this matter.

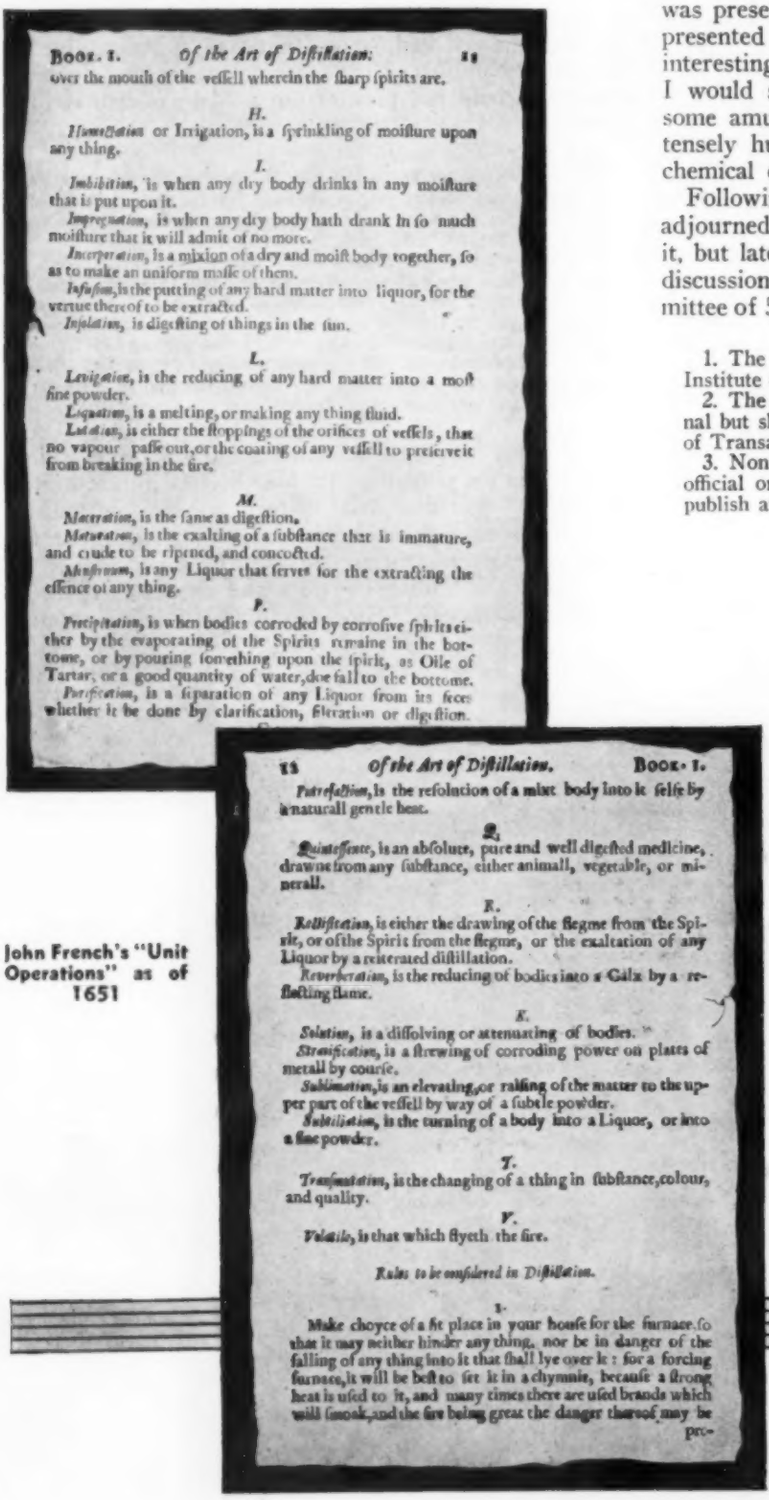
That committee, headed by a courageous and far-sighted chemical engineer, Charles F. McKenna of New York City, first launched a questionnaire to 600 members of the chemical profession in United States and Canada. Although three-fourths of the replies were found to favor the formation of the new society, it was decided in the interest of fairness that the opponents should be given an opportunity to advance their arguments and opinions. Accordingly a larger and open meeting was held at the Hotel Belmont in New York on Jan. 18, 1908. Twenty-one men attended the meeting and fourteen others sent in their views. Dr. John C. Olsen, who was present, of course, has carefully preserved and has presented me with a stenographic report of the intensely interesting discussion which occurred at that meeting. I would suggest that it can be read with profit—and some amusement—by all who are interested in the intensely human history of the beginnings of organized chemical engineering in this country.

Following hours of animated discussion the meeting adjourned without definite decision on the problem before it, but later after a complete transcript of the evening's discussion had been printed and sent to the entire committee of 50, a canvas was made on three propositions:

1. The proposed organization should be called the American Institute of Chemical Engineers.
2. The Institute should not attempt the publication of a journal but should confine its publication to a volume or volumes of Transactions.
3. None of the existing journals should be designated as the official organ of the society but members should be free to publish articles wherever they chose.

The poll of the committee of 50 brought forth 36 replies of which 22 were in the affirmative, six were negative, and eight were neutral, although three of the men stated that they would join if the organization were formed. There was no longer any reason for delay in forming the new society so a meeting was called for June 22, 1908, for this express purpose. Forty men attended and listened with enthusiasm to Chairman McKenna's stirring address entitled "The Justification of the American Institute of Chemical Engineers." I am not sure it needed any justification then—any more than it does now,—but Dr. McKenna's ringing words of 27 years ago still hold a thrilling challenge for all who carry on the work of the profession:

> YOU who call yourselves Chemical Engineers, who know the science and the art, who feel your potency and your latent powers, you are to blame if you do not demand to be heard, to show by your efforts what stock you come from, and to demand of educators that in the future the title of Chemical Engineer shall be clear, the training adequate, and the public encouragement the strongest.



Book. I. *Of the Art of Diſtillation:* 11

over the mouth of the veſſell wherein the ſharp ſpirits are.

H.

Humectation or Irrigation, is a ſprinkling of moiſture upon any thing.

I.

Imbibition, is when any dry body drinks in any moiſture that is put upon it.

Impregnation, is when any dry body hath drank in ſo much moiſture that it will admit of no more.

Incorporation, is a mixion of a dry and moiſt body together, ſo as to make an uniform maſſe of them.

Infuſion, is the putting of any hard matter into liquor, for the vertue thereof to be extracted.

Inſolation, is digeſting of things in the ſun.

L.

Levigation, is the reducing of any hard matter into a moſt fine powder.

Liquation, is a melting, or making any thing fluid.

Lutation, is either the ſtoppings of the orifices of veſſels, that no vapour paſſe out, or the coating of any veſſell to preſerve it from breaking in the fire.

M.

Maceration, is the ſame as digeſtion.

Maturation, is the exalting of a ſubſtance that is immature, and crude to be ripened, and concocted.

Menſtruum, is any Liquor that ſerves for the extracting the eſſence of any thing.

P.

Precipitation, is when bodies corroded by corroſive ſpirits either by the evaporating of the Spirits remaine in the bottome, or by pouring ſomething upon the ſpirit, as Oile of Tartar, or a good quantity of water, doe fall to the bottome.

Purification, is a ſiparation of any Liquor from its feces whether it be done by clarification, filtration or digeſtion.

12 *Of the Art of Diſtillation.* Book. I.

Putrefaction, is the reſolution of a mixt body into it ſelfe by a naturall gentle heat.

Q.

Quinteſſence, is an abſolute, pure and well digeſted medicine, drawne from any ſubſtance, either animall, vegetable, or minerall.

R.

Rectification, is either the drawing of the flegme from the Spirit, or of the Spirit from the flegme, or the exaltation of any Liquor by a reiterated diſtillation.

Reverberation, is the reducing of bodies into a Calx by a reflecting flame.

S.

Solution, is a diſſolving or attenuating of bodies.

Stratification, is a ſtrewing of corroding power on plates of metall by courſe.

Sublimation, is an elevating, or raiſing of the matter to the upper part of the veſſell by way of a ſubtile powder.

Subtiliation, is the turning of a body into a Liquor, or into a fine powder.

T.

Tranſmutation, is the changing of a thing in ſubſtance, colour, and quality.

V.

Volatile, is that which flyeth the fire.

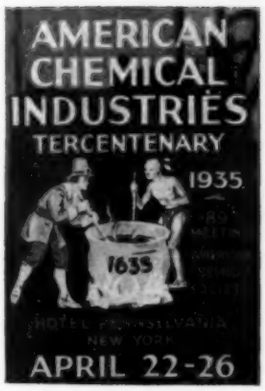
Rules to be conſidered in Diſtillation.

1.

Make choyce of a fit place in your houſe for the furnace, ſo that it may neither hinder any thing, nor be in danger of the falling of any thing into it that ſhall lye over it: for a forcing furnace, it will be beſt to ſet it in a chymnie, becauſe a ſtrong heat is uſed to it, and many times there are uſed brands which will ſmoak, and the fire being great the danger thereof may be pre-

John French's "Unit Operations" as of 1651

Through the whole development of the chemical industry in this country runs one common bond of interdependence—industrial research. At first but a narrow thread of scientific interest, that bond has grown to a mighty chain binding together many apparently diverse fields of activity. Early in the present depression Drs. Weidlein and Hamor published a stimulating book "Science in Action" (McGraw-Hill 1931) that traced the history of the development of industrial research in America, in a most interesting way as is evidenced by this article which is based almost entirely on that book. To it the reader is referred for a refreshing review of all of the ramifications of research in America.—EDITOR



3 CENTURIES of Chemical Industry in America

By EDWARD R. WEIDLEIN AND WILLIAM A. HAMOR

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FIRST manufactures in Colonial America—pot or soap ashes in 1608, glass in 1610, and leather in 1620, all in Virginia—were chemical in nature. But American chemical technology actually had its beginning in the pioneer work of John Winthrop, Jr., who landed in Boston in 1631, at the age of 25. He became interested in the production of alum, copper, glass, iron, potash, salt, saltpeter, tar, and other needed goods. With his uncle, Emanuel Downing, he carried out experiments on the preparation of indigo that entitled them to the honor of having conducted the first industrial research within the present borders of the United States. In 1662 Winthrop read a paper on tar before the Royal Society of London. In the early 1630s, the first tannery in New England was erected in the village of Swampscott, Lynn, Mass., by Francis Ingalls; the vats used by him remained there until 1825.

As soon as the American colonists began to manufacture for themselves, they encountered the opposition of the English industrialists and in consequence a number of restrictions were imposed on colonial manufactures. In fact, the people of England looked upon the North American colonies, especially those of New England, as their rivals in industry and trade. The British government was firmly committed to the theory that the colonies should produce raw materials only, depending upon the mother country for all manufactured articles. Nevertheless the production of iron, glass, paper, leather, hats, and woolen and linen goods continued to grow among the colonies.

From a technical standpoint, the colonial mills were abreast of the English and perhaps in advance of them in some instances. French travelers in America observed that power was applied to more uses than was common in Europe. The branches of manufacture that operated during the Revolution encountered almost every adverse technologic and commercial condition that such political vicissitudes could bring. The industries that survived this conflict were those that were dependent upon natural advantages of which they could not be deprived.

Among the American scientists of this period who became interested in manufacturing processes was James Woodhouse, professor of chemistry at the University of Pennsylvania from 1795-1809. Contemporaneous with Woodhouse, were the following chemists: Robert Hare, inventor of the oxyhydrogen blow-pipe (1802) who obtained calcium carbide, phosphorus, graphite, and calcium by the aid of electricity and is to be regarded as the earliest American experimenter in electrochemistry; Joseph Cloud, assay master at the Philadelphia Mint, who, in 1807, made an interesting research on a native alloy of palladium and gold from Brazil; John Harrison, the first manufacturer of sulphuric acid in this country (1793), an ingenious industrialist who made many innovations in practice; and Gerard Troost, professor of chemistry at the University of Nashville, who founded an alum factory at Cape Sable, Md., in 1814.

American chemical technology received developmental stimuli from the embargo of 1806 and the War of 1812 as evidenced by the general character of patents issued to chemical inventors. Previous to 1806, these patents related chiefly to distilling, salt manufacture, potash making, and the utilization of sperm oil and other fats for soap and candles. But after 1806, the inventive genius of American chemists began to be diverted into more modern channels. Between 1806 and 1814 there are

noted for the first time inventions that refer to subliming sulphur, dyeing silks and calicoes, bleaching refining camphor, waterproofing leather, making artificial mineral water, and manufacturing sulphuric acid, copper acetate, magnesia, and white and red lead.

The year 1806 marks the real awakening of industrial chemistry in the United States. The first Americans to go abroad for chemical training, Benjamin Silliman, John Gorham, and others, were returning from their studies in Europe; they soon contributed their share to the new movement. American publishers began to print practical treatises on chemistry—works of native writers such as Thomas Ewell, James Cutbush, Franklin Bache, and John Gorham, and reprints of European authors such as Jane Marcet, Joseph Black, Samuel Parkes, Thomas Thomson and Frederick Accum—and for the first time the attention of the public was called forcibly to the national importance of chemical industries. It is of great interest to mention that coal gas was manufactured for lighting in 1806. Four years later the manufactured products of the United States had attained a total value of approximately $120,000,000.

Table I—Early American Chemical Industries

Manufacture	First Manufacturer	Year	First Important Improvement	By Whom	Year
Sulphuric acid . .	John Harrison, Philadelphia, Pa.	1793	Platinum still for concentrating	John Harrison	1814
Gunpowder	E. I. duPont de Nemours & Company, Wilmington, Del.	1802	Potassium nitrate from sodium nitrate	DuPont	1868
White lead	S. Wetherill & Son, Philadelphia, Pa.	1804	The use of cheaper material from Mo. and Ill.	. . . . .	1850
Pharmaceutical . . chemicals . . .	Rosengarten & Sons Philadelphia, Pa.	1823	Ether and quinine 1823; morphine, 1832; strychnine, 1834	Rosengarten & Sons	. . . .
Varnish	P. B. Smith, New York, N. Y.	1828	Improvement of quality to create a foreign market	P. B. Smith	1836
Wood distillation	James Ward, North Adams, Mass.	1830	Manufacture of acetate of lime and wood alcohol	J. A. Emmons & A. S. Saxon	1867
Nitric acid	Carter and Scattergood, Philadelphia, Pa.	1834	Distillation apparatus	Edward Hart	1898
Hydrochloric acid	Carter and Scattergood	1834	Manufacture by modern methods	Charles Lennig	1869
Chlorine	Charles Lennig, Bridesburg, Pa. (Bleaching Powder)	1847	Commercial process for the electrolysis of sodium chloride	E. A. LeSueur	1893

Many problems of manufacturing were given scientific study in the United States during the period 1820-1860. James Cutbush, professor at West Point, made valuable contributions to pyrotechnics, but is chiefly remembered for his description, published in 1822, of the production of cyanogen by the action of nitric acid upon charcoal. Samuel Guthrie of Sackett's Harbor, N. Y., discovered chloroform, engaged in the manufacture of fulminating compounds, and devised commercial processes for the rapid conversion of potato starch into sugar (1832). In the same year, Benjamin Silliman was engaged by the Government to study agricultural problems. Lewis Feuchtwanger, known by his establishment for the manufacture and sale of "rare" chemicals, devised, in 1837, an expeditious method for the manufacture of vinegar, and later in 1872, studied the process of glass-making.

Then there was S. L. Dana of Lowell, Mass., for 50 years an acknowledged authority on technical chemistry, who devoted himself to industrial problems while holding a position of chemist with the Merrimack Mfg. Co., Lowell, Mass., from 1833-1868; he invented the "American system" of bleaching in 1838, and also gave attention to dyeing, fertilizers, and lead poisoning. C. S. Homer introduced the use of Perkin's aniline dyes in the Pacific Mills, Lawrence, Mass., about 1860. Later in 1867 he specialized in paints and varnishes.

Other scientists of this period, who busied themselves in the field of industry and inspired hosts of younger men were St. Julian Ravenel (1819-1882) who made experiments upon converting So. Carolina phosphate rock into commercial fertilizer; J. C. Booth, of Philadelphia, noted for his work on beet sugar (1842), the production of gelatine (1842), and illuminating oils (1862), as well as for being the founder of an active firm of chemical consultants; John Dean of Boston, Mass., who investigated the value of different kinds of prepared vegetable foods in 1844; David Alter of Freeport, Pa., one of the discoverers of spectroscopy, who began the manufacture of bromine in 1846 and later became a coal oil technologist; Charles Lennig of Philadelphia, the first to manufacture bleaching powder in the United States (1847) and who afterwards (1869) introduced the manufacture of hydrochloric acid by modern methods; L. C. Beck, professor of chemistry in Rutgers College, who made valuable observations on bleaching and disinfecting compounds and who was an authority on breadstuffs (1848); A. C. Twining, a chemical engineer of the fifties, who invented an ice machine; C. M. Wetherill (1825-1871), who conducted researches on illuminating gas in 1854 and on the manufacture of vinegar in 1860, and who was the first chemist of the U. S. Dept. of Agriculture (1862); Benjamin Silliman, Jr., the author of "Technochemical Classics on Pennsylvania Petroleum" (1855), California petroleum (1865-67) and on the combustion of fuel (1860); E. N. Horsford (1818-1893), who studied bread-making and condensed milk manufacture and worked out processes for preparing phosphoric

acid (1856); Henry Wurtz of New York, who played an important part in the development of the manufacture of glycerine in 1858, and J. M. Ordway of the M. I. T., who investigated the manufacture of sodium hydroxide in 1858 and of sodium silicate from 1861-65.

After 1860 American manufactures increased with wonderful rapidity. To illustrate this growth may be cited the case of the familiar manufacture of fertilizers, production of which rose from the value of less than $900,000 in 1860 to almost $6,000,000 in 1870, and nearly quadrupled during the next ten years. Manufacture of chemical fertilizers in the United States began about 1850, and the Herreshoffs of Rhode Island made fish oil and scrap, as early as 1863. Joseph Wharton, of Philadelphia, deserves special mention in the history of technology in America. Wharton erected at Bethlehem, Pa., in the year 1860, a spelter works of 16 Belgian furnaces which produced over 3,700,000 lb. of zinc in 1862.

Many chemists rendered service to the advancement of industry in the sixties and the seventies. B. F. Craig of the laboratory of the Army Medical Museum at Washington, D. C., was engaged in the manufacture of explosives; Frederick Hoffman, of New York, was an authority on organic colors and medicinal chemicals, while E. R. Squibb distinguished himself by his studies in pharmaceutics. C. F. Chandler, Columbia University, was also productive; his early studies dealt with water for locomotives (1865), water supply of New York (1868-70), purification of illuminating gas (1870), kerosene (1871), condensed milk (1871). Another chemist called upon by the gas industry was Henry Wurtz, who made improvements in the methods of purifying water gas (1867); jointly with Silliman (1869) he elucidated the processes of manufacture. In 1880 the Municipal Gas Co. of New York employed A. H. Elliott for research on water gas production. Other scientists and industrialists included Henry Morton of Stevens Institute, who conducted researches on petroleum (1872-74); J. P. Kimball of Lehigh University engaged in work on ferrous metallurgy; J. F. Babcock of Boston, Mass., an expert on wood preservation; T. M. Drown, professor of chemistry at Lafayette College, the author of important papers on ferrous metallurgy; H. M. Pierce was most active in the promotion of wood distillation; C. E. Avery of Boston, Mass., laid the foundation for the manufacture of lactic acid; Charles and Nelson Goodyear and A. G. Day are known for their work on rubber; R. C. Kedzie (1823-1902) started the Michigan beet sugar industry and added to the knowledge of fertilizers.

Sufficient has been presented to show that American chemists and engineers have been constantly engaged in investigating problems of manufacturing. The space available will not permit the recounting of more than a few of the many contributions during the most modern period of our industrial history, from 1880 to date. Perhaps it will be sufficient to call the roll of those whose services to the industries have been recognized and honored principally by the presentation of the Perkin Medal, which Dr. Arthur D. Little has referred to as the "Badge of Knighthood in American Chemistry." This medal is awarded annually by a committee representing five national chemical societies, for the most valuable work in applied chemistry.

First American to receive the award was J. B. F. Herreshoff, who made improvements in the chamber process for manufacturing sulphuric acid and also was active in the development of contact processes. In addition he devised a roasting furnace for pyrites fines and a copper smelting furnace and was a technical leader in the field of the electrolytic refining of copper. Arno Behr was similarly productive in the technology of corn products. He has to his credit the development of processes for manufacturing grape sugar, crystallized dextrose, and mill starch and for utilizing various byproducts of the industry.

E. G. Acheson was a man of prodigious ability. He invented the two abrasives, carborundum and siloxicon, the two lubricants, Aquadag and Oildag, and also artificial graphite, graphitized electrodes, soft graphite, and deflocculated graphite. Charles M. Hall was the inventor of the process for manufacturing aluminum by the electrolysis of its oxide, alumina, in a fused cryolite bath—a discovery that immortalized his name. Herman Frasch worked out a process for recovering sulphur from Canadian and Ohio petroleum products and also a method of mining sulphur by melting it in the earth by the use of superheated water and then pumping the fusion to the surface. James Gayley, a famous metallurgical chemist, invented the dry-air blast for the manufacture of iron. J. W. Hyatt developed the manufacture of celluloid and thereby created an important industry.

Edward Weston, an early associate of Edison, has been a powerful factor in electrochemical research. He has achieved fame through his researches on the electrodeposition of metals, electrolytic refining of copper, construction of electric generators and motors, arc and incandescent illumination, electrical measuring instruments, and the Weston standard cell. L. H. Baekeland, great among the greatest of our times—discovered Velox photographic paper and the synthetic resin Bakelite. Ernst Twitchell invented and developed the use of organic sulphoacids as catalysts in the hydrolysis of oils and fats for the production of fatty acids and glycerine. A. J. Rossi enriched metallurgy by his studies of titanium steel and other titanium alloys. F. G. Cottrell, formerly director of the Fixed Nitrogen Research Laboratory, U. S. Dept. of Agriculture, has investigated fruitfully the recovery of helium from natural gas wells, the electrical precipitation of suspended particles in gases, and the fixation of atmospheric nitrogen.

W. R. Whitney, the very learned research director of the General Electric Co., has had an important part in the development of metallized incandescent filaments of gem lamps, tungsten lamps, of gas-filled lamps, of insulating materials and alloys, and of new electrical equipment. W. M. Burton is well known as the inventor of a high-temperature process of cracking petroleum under pressure. He was the first to demonstrate that motor fuel can be safely made on a large scale by the treatment of high boiling point residues of petroleum distillation. M. C. Whitaker, a chemical engineering celebrity of New

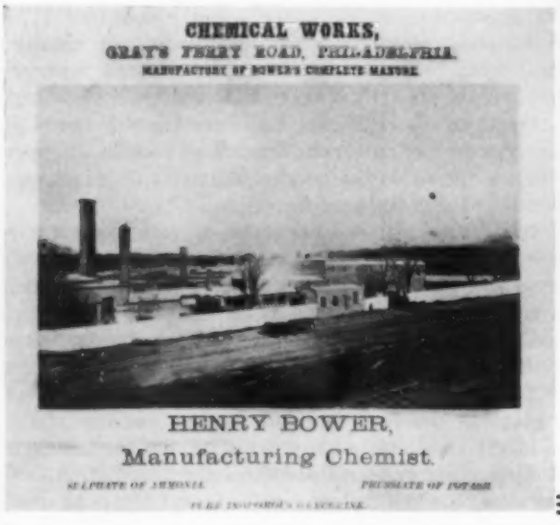
York City, has made many improvements in the manufacture of alcohol, ethyl acetate, acetone, and other solvents, and in the utilization of catalytic processes in chemical industry.

F. M. Becket of the Union Carbide & Carbon Corp. is the inventor of processes for the extraction of rare metals from ores, for the reduction of rare metals and alloys, and for the manufacture of calcium carbide. Hugh K. Moore of the Brown Co., Berlin, N. H., has developed electrolytic processes for the manufacture of chlorine and caustic soda, and for the recovery and utilization of by-products in the pulp and paper industry. Richard B. Moore, who was on the faculty of Purdue University, was highly respected for his researches on helium and the radioactive elements. The late John E. Teeple conducted beneficial technical work in the manufacture of chemicals, especially acids, alkalies, and chlorine; he also effected improvements in the distillation of hardwoods and in the recovery of potash and borax at Searles Lake, Calif. Irving Langmuir of the General Electric Co., Nobel prize winner in 1933, is illustrious for his studies in the fields of low pressures, convection, radiation of heat, vapor pressures of metals, vacuum pumps and vacuum gages; atomic and crystal structure, electronic and ionic currents, high power vacuum tubes, theories of adsorption, evaporation, and passivity. He has also been the first to apply argon and nitrogen in tungsten lamps; he gave us the atomic hydrogen flame for welding. E. C. Sullivan of the Corning Glass Works has developed special glasses for heat resistance, for the transmission of certain light rays, and for laboratory research work. The late Herbert H. Dow, of Midland, Mich., stands out as a poineer who made important contributions in the production of bromine, chlorine, alkali, metallic magnesium, magnesium salts, phenol, aniline and organic compounds.

When Arthur D. Little, extraordinary interpreter of the value of research to industry and commerce, received the 1930 imprint of the Perkin Medal, his classical address pointed the way toward what future progress is likely to come from our chemical laboratories: "Since advances in chemistry react on every industry, while, conversely every progressive trend in other industries makes new demands on chemistry, we may look with confidence to the chemical industries for contributions which should go far toward supplying stimulus essential to the revival of our prosperity and which the stationary or obsolescent industries can no longer furnish. . . . Chemistry is a creative science and the first chapter of its Book of Genesis is not yet written."

Charles F. Burgess, of the Burgess Laboratories in Madison, Wis., has successfully applied industrial research to the manufacture of electrochemical products. He has contributed notable advances to cellulose technology and to many applications of science to the construction industry. George Oenslager's contributions to the rubber industry, notably the development of organic accelerators for vulcanization, effected savings to motor car owners estimated to be in the magnitude of $100,000,000 annually. Colin G. Fink, resourceful inventor in electrochemistry and electrometallurgy, is almost as well known for his hobby, the restoration of ancient bronzes and other works of art, as for his valuable industrial researches in the electro-deposition of chromium and tungsten.

Most recent and youngest of all the Perkin medallists is George O. Curme, Jr., vice-president and director of research of the Carbide & Carbon Chemicals Corp., who, on Jan. 11 of this year, received the award for achievements in the development of a synthetic, aliphatic, chemical industry in the United States. This contribution is, in a sense, a fitting climax to all the three hundred years of industrial research so sketchily reviewed in this article. It is most significant that Carbide's is primarily and typically an American achievement, based on American raw materials and carried forward by processes developed by chemists and chemical engineers trained for industrial research in American colleges and universities.

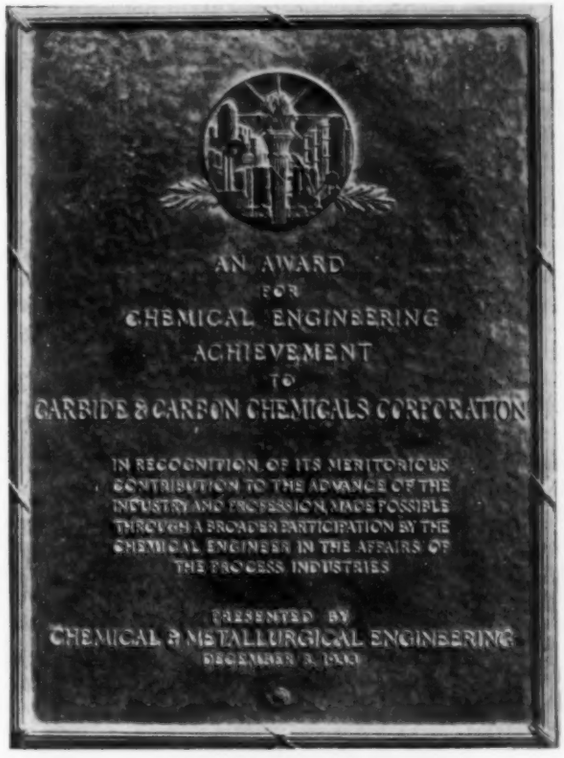


An American chemical industry and operating staff of 60 years ago—The flagstaff at the right of the plant, and the long buildings, are the U. S. barracks used during the Civil War. Both pictures supplied through the courtesy of William H. Bower, president of the Henry Bower Chemical Mfg. Co., and son of the founder.

AWARDING

Chemical Engineering Achievements and Developments

Announcing plans for the second biennial recognition of company or group effort



IN MAY, 1933, this magazine first announced a plan for a biennial award for chemical engineering achievements. Among the multiplicity of medals, prizes, honorary degrees and other forms of recognition that are periodically bestowed upon chemists, engineers and executives in chemical and process industries, this award is unique in that it is given to a *company* rather than to an *individual*. Thus, it is primarily a recognition of coordinated group effort and attainment. For this reason it is believed that it leads to a more accurate and fairer appraisal of merit than is sometimes the case when an individual is singled out for honors which he would prefer to share with many co-workers as well as with the corporate organization that has supported and made possible the group achievement.

The primary purpose of the editors of *Chem. & Met.* in establishing this unique award was to encourage a broader participation of the chemical engineer in the affairs of the process industries. They believe that both the industry and the profession would be benefited if the chemical engineer might make his influence felt, not only in purely technical phases of production and distribution, but in executive and administrative capacities where, for reasons that are changing with the times, the financier, the lawyer and the so-called "business man" have long reigned supreme. That more chemical engineers have not attained positions of greater corporate responsibility is as often a criticism of their capacities as of the system under which industry operates. Therefore, it was hoped that this award might in some measure stimulate both the individual engineer and the company management toward a broader viewpoint of their mutual opportunities and responsibilities.

The first award, made at the time of the last National Exposition of the Chemical Industries in New York in December, 1933, was presented to the Carbide and Carbon Chemicals Corporation for its meritorious contribution in the building of a synthetic aliphatic chemicals industry in the United States. That pioneer development was described in text and pictures in an unusual article appearing in the November, 1933, issue of *Chem. & Met.* (pp. 562-70). To it the reader is referred for an interesting account of a purely American chemical engineering achievement. From the outset it was planned, constructed, operated and managed by men who, in fact if not in name, are chemical engineers.

At the time the award was presented, William Felton

Barrett, chairman of board of the Carbide and Carbon Chemicals Corporation, made an illuminating commentary on the participation of chemical engineers in the activities of that corporation. He said: "The term 'chemical engineer' may be defined in an extremely broad sense or again may be defined in terms of the various courses leading to a Ch.E. degree in our universities. In the belief that *Chem. & Met.* uses the term in the broader meaning—from that angle it may be pertinent to state that every officer of the corporation and every major department head is or started his career as a technical man with one or more degrees. It may be of interest to observe that the corporation employs about 200 men holding technical degrees. Of these men approximately one-third are employed in research and development, one-third in engineering and operation, and one-third in sales activities and executive capacities." Such a situation is perhaps unique among American chemical industries, but it points clearly in the direction of the ideal behind this award for chemical engineering achievement, namely, that "broader participation by the chemical engineer in the affairs of the process industries."

Mr. Barrett, on this same occasion, also explained how it had been possible to develop a corporation in which "turnover" of technical personnel had been practically nil. He said: "In building our organization, we have attempted to use the greatest care in selecting our young technical men, and although selections are generally made with specific duties in mind, all new men are first given a period of work as cadet engineers. In this period an attempt is made to determine the specific adaptability of each individual and he is then assigned to a department in which it is felt he will be able to work most efficiently. It has not always been possible in the first or second assignment to find the environment best suited to the individual, but we have been singularly fortunate in ultimately placing most of these younger men in types of work in which their inherent abilities have been given an opportunity to grow and develop. Through this method of placing our technical men, there has resulted a wider distribution of chemical engineers into all phases of our activities, not only in engineering and production, but also in research, development, sales and management as well."

What Is Achievement?

Chemical engineering achievement can, of course, be defined in many different ways. One definition cited in the May, 1933, announcement (see *Chem. & Met.*, vol. 40, pp. 226-9) is as follows: "The successful large scale commercial development of a process, group of processes or of a company's entire business based on chemical research and actively organized, developed and operated through chemical engineering control or direction." Other views that have been expressed by the various members of the Committee of Award include a recognition of outstanding improvements in yield and quality of product or in the development of an important piece of equipment, the design of which exhibits a high order of chemical engineering ability.

Albert E. Marshall, president of the American Institute of Chemical Engineers, who has agreed to serve as chairman of the 1935 Award Committee, writes: "I have long been impressed with the rather narrow limitations of conditions surrounding the majority of medals and their equivalents presented in chemical industry. I have come to look upon the development of a multiplicity of awards as nothing more than the natural result of the growth of chemistry and chemical engineering and the need for specific awards in order that real talent and accomplishment can be properly recognized. For this reason I strongly feel that the type of achievement which should be recognized by the *Chem. & Met.* award should not be narrowly subscribed by fixed and inflexible conditions. For instance, I hope that this award might at some time go to a firm which has a high record as a direct result of the close cooperation of the executive, engineering, sales and research divisions—even though there might be no single outstanding accomplishment to the corporation's immediate credit. In other words, the plans for this particular award should be kept sufficiently flexible to permit the recognition of chemical engineering achievement in its broadest sense."

In keeping with the views so well expressed by Chairman Marshall, there is to be a minimum of red tape and

COMMITTEE OF AWARD

ALBERT E. MARSHALL
Chairman
Consulting Chemical Engineer, President, American Institute of Chemical Engineers

CHARLES E. ADAMS
President, Air Reduction Co.

CHARLES BELKNAP
President, Merrimac Chemical Co. Chairman of the Executive Committee Manufacturing Chemists' Association

HARRY A. CURTIS
Chief Chemical Engineer, Tennessee Valley Authority, Vice Pres., American Institute of Chemical Engineers

JOHN VAN NOSTRAND DORR
President, The Dorr Company, Inc.

ARTHUR D. LITTLE
Consulting Chemical Engineer

WALTER A. SCHMIDT
President, Western Precipitation Co., Director, American Chemical Society

M. C. WHITAKER
Vice Pres., American Cyanamid Co. Director, American Chemical Society

ALFRED H. WHITE
Professor of Chemical Engineering, University of Michigan

SIDNEY D. KIRKPATRICK,
Secretary
Editor, Chemical & Metallurgical Engineering

formal procedure in the rules and conditions governing this second award. These regulations, as they appear herewith, are therefore subject to the broadest interpretation which the committee and the readers of these pages wish to place on this. Your comment, criticism and suggestions will always be welcome.

Beginning with the May issue the editorial pages of *Chem. & Met.* will attempt a systematic review of some of the outstanding chemical engineering achievements and developments contributed by different companies in the process industries. It is hoped that these reviews may be supplemented by many voluntary suggestions received from individual members of the industry and profession. On or about Oct. 1, 1935, these records, in the form of a series of brief statements outlining the achievements of a number of companies, will be placed before the members of the Committee of Award, whose selection of the outstanding contributions will be announced in the October issue of *Chem. & Met.* The winning achievement will be described in detail in November and a bronze plaque similar in design and format to the one shown on a preceding page, will be presented during the fifteenth National Exposition of Chemical Industries in New York City, Dec. 2-7, 1935.

Rules and Conditions Governing

AWARD FOR CHEMICAL ENGINEERING ACHIEVEMENT

1. The purpose of this award is to give public recognition to the company in the process industries which through the effective use of chemical engineering in any phase of its activity has contributed the most meritorious advance to the industry and profession.

2. The award is to consist of an appropriate bronze plaque suitably engraved to indicate the nature of the achievement and the name of the company to which it is presented.

3. The second award is to be made at the time of the National Exposition of Chemical Industries which will be held in New York City during the week of Dec. 2, 1935. The award applies only to industrial developments that have come to fruition since December, 1933. Subsequent awards will be confined to developments occurring in the intervals between the National Expositions of Chemical Industries.

4. The award is to be made only to a company in the process industries since it is a recognition of the achievement of a corporate organization rather than that of any individual or department within a company. However, any company or any of its subsidiaries would be eligible for the award on the basis of any number of achievements brought to the attention of the committee.

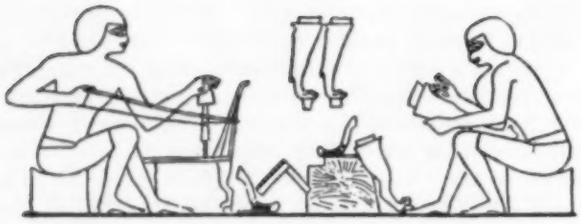
5. The Committee of Award shall consist of nine men, recognized as leaders in the industry and profession. It should include representatives of the American Institute of Chemical Engineers and the Manufacturing Chemists' Association. One of the members of the Committee of Award is to be designated as the chairman, and the editor of CHEM. & MET. is to serve as secretary of the committee but without voting power. It is expressly understood that no member of the committee would be asked to pass on the merit of entries made by any company with which he is affiliated. In other words, any member would have the privilege of withdrawing at any time should the consideration of a company's name prove likely to be embarrassing in personal or business relations. In such case the member of the committee would be reported as "not voting."

6. It is to be the function of the committee to review the achievements in the field, to receive suggestions from all sources and to determine which company has, in its judgment, contributed the most meritorious chemical engineering achievement during the interval under consideration.

7. Any company in the process industries desiring to be considered for this award may file an application merely by answering the following inquiries:

(a) What is the nature of the achievement?
(b) During what period was it effected?
(c) To what extent have chemical engineers participated in this development?
(d) Are there any supplementary records, data, articles or references which you would care to include as pertinent to a fair consideration of this achievement?

8. It is expressly understood that the award is not to be limited to those companies who file formal applications with the committee, since suggestions are welcome from any source that will assist in directing the attention of the committee to achievements of companies that should have consideration. All communications should be addressed to the Secretary, Committee of Award, CHEMICAL & METALLURGICAL ENGINEERING, McGraw-Hill Building, New York City.



Egyptian bow-string drill (after Erman-Ranke)

PROGRESS IN

FROM the very beginning, progress in the development of chemical processes has been so closely linked with progress in chemical equipment that the two are inseparable. Better equipment has made it possible to improve processes or to introduce entirely new ones. This in turn has frequently resulted in further improvements in equipment. Much the same idea has been expressed in the observation that one of the outstanding results of the introduction of steam power was the use of machines to make other machines.

Examples of this close interrelationship will be found in nearly all of the process industries. Thus, the fact that the chemical industry was able to supply sulphuric acid in large quantities made possible the electrolytic refining of copper. This made available to the process industries a better grade of copper for the fabrication of equipment. Similarly, improvements made by Linde in low temperature refrigeration and rectification equipment led to the commercial production of oxygen by the liquid-air process. This, through the oxyacetylene process of welding and cutting metals, provided a new tool for the fabrication of process equipment.

While chemical engineering is a relatively modern development, it is necessary to go back far beyond the dawn of history in order to trace the beginnings of the processes used to fabricate the tools of the modern chemical engineer.

Man's first implements probably were simply sticks, stones of convenient size and shape, and in certain localities shells for scraping and cutting. Gradually these primitive people learned how to chip stones into more useful shapes, such as hammers, mallets, axes, knives, scrapers, and borers for hide and wood. With these they were able to make more effective use of wood and other materials. Furthermore, the facility with which clay could be shaped must have appealed to primitive man almost from the beginning. In localities where stones were scarce, clay was shaped into brick. Remains in Mesopotamia, dating back to 3500 B.C., reveal the use of unburned or sun-dried brick for buildings, and the use of burned brick for paving.

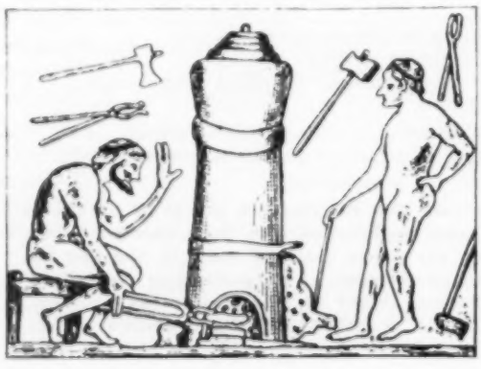
Pottery was also made from clay fashioned into shape by hand. At first the pieces were simply hardened by drying in the sun. With the increasing knowledge of fire, it was discovered that the strength of pottery could be greatly improved by baking. For ages, tools and methods used in pottery making remained the same. At a comparatively late date, the idea of forming pots and jars on a rotating wheel was developed independently by many different races.

The oldest examples of glazed pottery are found in Egypt, Syria and Persia. Modern chemical stoneware might be said to trace its ancestry to this period, although the salt glaze was probably developed somewhat later.

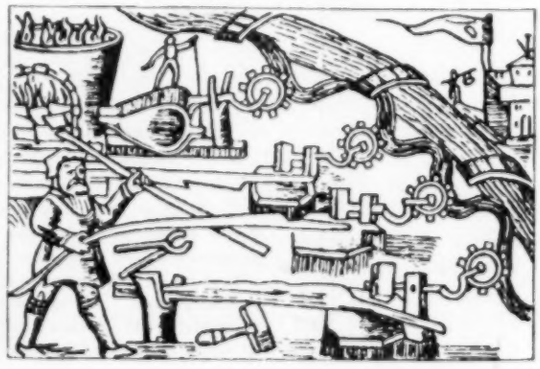
Glass, another material of profound interest to the chemical industries, was discovered at least as early as 2500 B.C. At first, vessels were formed by welding together rods or threads of softened glass around a core of sand. About 1200 B.C. glass pressing in molds was begun by the Egyptians. The most important early method of forming, glass blowing, was not invented, however, until about the beginning of the Christian era.

Early Metal Working

The first metals used by man were the relatively few that occurred in a free state in nature: gold first, because of its bright color; later copper, less easily recognized as a metal because of surface discolorations; and in certain localities meteoric iron. At first, because of their scarcity, they were probably used as ornaments. It was soon found that gold could be hammered to shape and that pieces could be joined by hammering together. Copper and meteoric iron were harder than gold and their greater utility as tools and implements was gradually recognized. Native copper was apparently fairly abun-



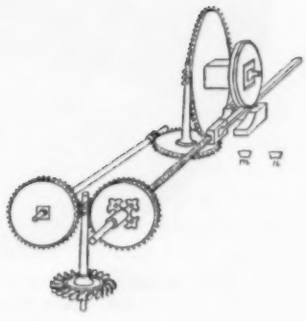
Early Grecian ancestor of the blast furnace



Swedish conception of water-powered forge and forge hammers

FABRICATING THE TOOLS OF MODERN INDUSTRY

By G. O. CARTER and A. G. WIKOFF
The Linde Air Products Co.
New York, N. Y.



dant and widely distributed in the ancient world. Hammered copper has been found in Chaldean remains that go back to 4500 B.C.

When fire became known, primitive man learned a new way of shaping his metal by melting and casting in sand or clay, or, later, in molds carved in stone. But from the melting of native metal, it was still a big step to the smelting of metal from the ore. The indications are that copper ores were the first to be smelted. In some localities the copper ores were associated with other ores, and thus the early bronzes were produced by the smelting operation.

The smelting of iron came at a much later date, probably because native iron is so rare that primitive man had no clue to the occurrence of iron ores. The product of the primitive smelter was a pasty mass of wrought iron, which was refined and shaped by hammering. Furnaces capable of giving a temperature high enough to produce molten iron were not developed until the 14th century A.D.

Fortunately, wrought iron has the property of being readily joined or welded by hammering or forging at temperatures well below its melting point. This property was quickly discovered and throughout the ages forge welding has been used to fabricate wrought iron equipment. Subsequently it was found that heating wrought iron in contact with charcoal improved the properties of the metal, and steel came into limited use.

In addition to cold working, forging and casting, many other fabrication methods were known to the ancients. Early Minoan pottery (about 2000 B.C.) copied from metal objects clearly indicates the heads of rivets that joined the original metal parts. Bronze bowls found in Crete and dating back beyond 1000 B.C. have loop handles riveted on their edges. One large bowl, over 4 ft. in diameter, is formed by joining together seven hammered sheets.

Soldering of gold was known to the Egyptians and was widely used in jewelry. They also knew how to enamel on metal and thus established the basis for modern fabrication of enameled iron process equipment.

The art of making hollow castings (of bronze) was developed about the middle of the 6th century B.C.

The ancients were thus familiar with rudimentary forms of many of the fabrication methods that are in use today. Biblical references emphasize the fact that many fabricating trades were well established long before the dawn of the Christian era.

Above: Leonardo's metal-working rolls (after Beck); and at left, blacksmith shop of early 16th century, according to Agricola, showing water-powered forge bellows and trip hammer

▼

Fabrication in the Middle Ages

During the dark ages in Europe, where progress was practically at a standstill, science and industry flourished in Arabia. The Arabs discovered many new chemical substances, such as alcohol, potash, silver nitrate, corrosive sublimate, and nitric and sulphuric acids. They were experts in working all the then known metals—gold, silver, copper, bronze, iron, and steel. They made glass and pottery, paper, leather, sugar from sugar cane, many kinds of wine and were familiar with fertilizers.

In the meantime in Europe a certain amount of prog-

Modern fabrication of a pressure vessel, using Lindewald process

ress was being made. Of particular importance was the gradual increase in the size of furnaces available for smelting iron ore. The use of an air blast supplied by some type of bellows or water blower arrangement resulted in higher furnace temperatures. About 1350, furnaces were developed which were capable of producing molten cast iron. While this made iron available in much larger quantities than had previously been known, it was many years before full advantage was taken of this development in the fabrication of equipment.

During the Middle Ages production of chemical commodities was naturally limited to what would now be termed small scale batch production. Wood figured largely in the fabrication of structures and supports of all types as well as for tanks and vats. Furnaces were constructed of brickwork. Pottery vessels, frequently of intricate design, were used for distillation. Evaporation was carried out frequently in iron pans supported in a setting of brickwork and heated directly by a fire of straw or wood.

In this period, as has been equally true of all times, including the present, expenditures for military purposes were not subject to the limitations which govern expenditures for industrial use. In the latter part of the 14th century large guns were made of wrought iron bars or rods beaten and welded together lengthwise and reinforced by iron rings around the outside. One cannon of this type, a famous bombard built in 1382, was of 25 in. caliber.

The Industrial Revolution

In the industrial revolution which took place in the 18th century there occurred a series of mechanical inventions which supplemented each other in the peculiarly coordinated fashion which is characteristic of so many phases of mechanical progress. The mere invention of improved machinery would have had relatively little effect, had it not been supplemented by the development of steam power for the operation of the machinery. Similarly the tremendously increased production made possible through the use of machinery would quickly have paralyzed the existing distribution systems, if there had not been developed new and better transportation.

It was during this period that necessity began to develop the science of plant location. In the iron industry, where charcoal had been used since the earliest times, the plants were necessarily located near large wooded areas. As the available supplies of wood for charcoal production became depleted it was necessary to search for another reducing material. This was found in the form of coke, which was first successfully used in the reduction of iron about 1713 in England.

The invention of the steam engine in 1769 made available a source of power for supplying a more constant blast of air to the iron furnaces as well as a source of power for operating machinery. In 1784 the first rolling mill was introduced and about the same time the puddling method of making wrought iron was developed. The development of railroads and steamboats, beginning about 1825, had a powerful influence on the metal-working industry. These new transportation industries provided a tremendous market for iron in a variety of forms. The manufacturing facilities developed for the production of these materials were also made available for use by other industries in the fabrication of machinery.

Prior to 1870 the principal metallic materials were cast iron and wrought iron. As foundry experience was gained, castings were produced in a constantly increasing variety of types. Wrought iron was available in rolled form. For the fabrication of equipment from wrought iron the processes of riveting, bolting and forge welding were widely used. The development of the steam hammer by Nasmyth, in 1834, provided a means for shaping and refining larger masses of wrought iron. It extended the range of forge welding by making it possible to apply the same principles in building much larger equipment.

During this period steel was produced in relatively limited quantities by the cementation and crucible processes.

Castings and rolled or forged shapes can seldom be used as machine parts without additional operations, such as drilling, milling, finishing, etc. Consequently the parallel development of machine tools was a most important factor in progress. Many early machine tools were derived from the lathe, which in simpler forms was known to the Egyptians and natives of India.

Modern Methods

The wide commercial availability of steel resulting from a long series of discoveries beginning with the Bessemer process, in 1856, introduced the modern era.

The low-carbon steel produced in Bessemer and open hearth furnaces quickly found wide use in the form of castings, forgings, rolled plate and shapes, and pipe. Improvements were made in the older fabrication methods, such as riveting and forge, or hammer, welding.

Introduction of electricity as a new, easily distributed source of light, heat, and power marks a further important step in progress. To the chemical and metallurgical industries it meant the commercial development of electrochemical and electrometallurgical processes. Early experiments with electric-arc furnaces led to the production of ferro-alloys, which were at once utilized in improving the quality of iron and steel. This has culmi-

nated in recent years in the production of a wide range of alloy steels, possessing superior qualities for many purposes.

The rapid increase in the number of commercial metals and alloys brought with it a definite need for improved fabrication methods. It is significant that the new methods, comprising modern welding, were already in process of development as the need arose. One of the first of these, electric-resistance welding, dates from Thompson's inventions about 1880.

Of more direct interest in the fabrication of chemical engineering equipment, however, was the development of the fusion welding processes, oxyacetylene welding and electric-arc welding. These are characterized by their ability to produce strong, tight, permanent joints in a wide range of metals and alloys. The adaptability of fusion welding so far exceeds previous methods of fabrication that it has been a most important factor in the commercial development of chemical processes.

Fusion welding was not new in principle, but previous methods had been limited to the lower-melting-point metals, such as lead. While the oxyhydrogen blowpipe was suggested by Robert Hare of Philadelphia about 1805, it remained a laboratory process until the commercial production of oxygen. The air-hydrogen blowpipe invented about 1837 made possible the fusion welding of lead, or lead burning, which supplanted soldering in the fabrication of lead acid chambers and other chemical equipment of lead. The temperature of the air-hydrogen, or even the oxyhydrogen, flame was not high enough, however, to permit fusion welding of steel and other metals having relatively high melting points.

In the early years of the 20th century the high temperature oxyacetylene flame began to be used for the fusion welding of steel, cast iron and other metals. Oxygen was made available commercially through the Linde liquid air process, first placed in operation in 1902. The first plant in the United States for the production of oxygen by this method was opened at Buffalo in 1907. Acetylene was made available as a result of the electric-furnace production of calcium carbide by Morehead and Willson, at Spray, N. C., in 1892.

The suggestion to use the electric arc for the fusion welding of metals was made shortly after the development of the carbon-arc light about 1880. At first a carbon electrode was used to form the welding arc. Later a metallic electrode was used. This led to the metallic arc process, which with its subsequent developments has become relatively much more important than the carbon-arc process, although the later is still used for certain purposes.

Progress in Fusion Welding

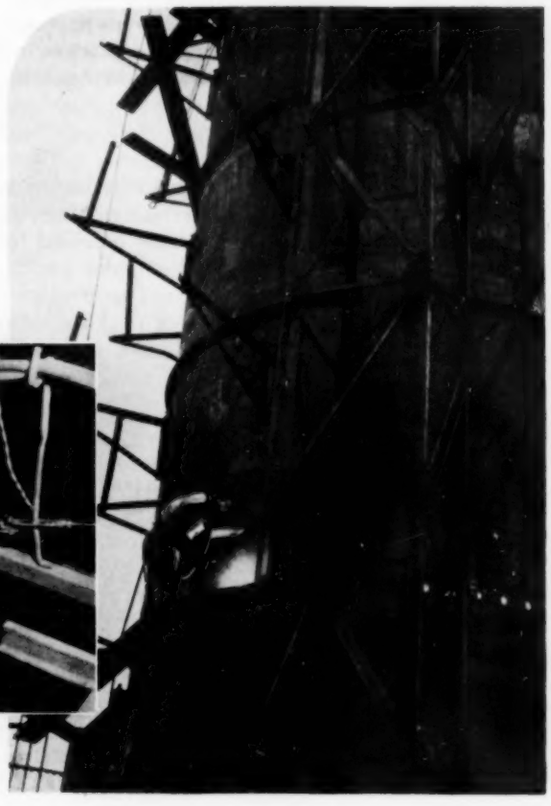
At first the application of the fusion welding methods was limited largely to the repair and reclamation of broken metal parts. The methods were first applied to steel and iron, as these are the most widely used metals. As experience was gained, techniques were developed for welding the other commercial metals. The World War period gave tremendous impetus to the spread of fusion welding and particularly emphasized its value as a fabrication method. Following the War, the problems of production welding received careful engineering study, with the result that welding is now done under complete managerial control, exactly the same as any other production method, while operating records of numerous items of welded process equipment have established confidence in fusion welding as a fabricating method. Concrete evidence of this is found in the fact that since 1931 many codes permitting fusion welding have been issued or are in preparation.

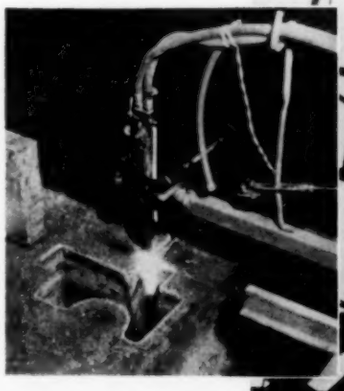
Oxyacetylene Cutting

The utility of fusion welding as a fabrication method has been supplemented by oxyacetylene cutting. This method, now widely used, provides the fastest and most economical method of cutting and shaping iron, steel, and many ferrous alloys. The idea developed from the metallurgical operation of tapping a furnace by means of an oxygen jet or oxygen lance. About 1905 the process was introduced commercially through the development of suitable cutting blowpipes, both hand and machine operated.

As a result of all of these developments, there is available to the process industries a variety of fabrication procedures capable of meeting any demands. Continued progress is assured through the efforts of trained research organizations, which work constantly to improve present methods and to develop new ones.

Stable-arc welding a 15-ft. diameter by 55-ft. bubble tower





Automatic shape-cutting machine

A—Sea. B—Pool. C—Gate. D—Trenches. E—Salt basins. F—Rake. G—Shovel.

Fig. 1—Evaporation, materials handling, flow of liquids, settling and crystallization, all these are among the unit operations in an ancient salt works, described by Agricola

LET'S LOOK AT

By JOHN H. PERRY
Editor-in-Chief, Chemical Engineers' Handbook
Chemical Engineer and Physical Chemist
Grasselli Chemical Co.
Cleveland, Ohio

CHEMICAL ENGINEERS seldom use history as a practical and useful tool of their profession. Even the detailed technical histories, glibly referred to as "the prior art," are too often left to the tender mercies of the patent attorney. This neglect is not so evident in other professions. The importance of clinical records to physicians, of legal precedents to lawyers, is familiar to all of us. The military engineers in their war colleges continually study and analyze the strategy of old battle plans and results and compare the tools of ancient and modern warfare. Mathematicians, astronomers, architects, biologists make consistent and frequent use in their daily work of the historical records of their professions. Why, then, does not the chemical engineer more commonly utilize the experience of his professional predecessors as a valuable tool?

The average chemical engineer is as keen and resourceful as any other engineer or professional man, but he should appreciate more fully and use more frequently the experiences of the past. One of the reasons for the comparatively limited use of the older chemical engineering literature by the chemical engineer lies in the fact that our profession is extremely young as an entity, particularly in comparison with most of the other branches of engineering. Another probable reason is that our literature, which is so much older than our formal organization, is scattered; although it cannot actually be said to be in a chaotic state, it certainly is not readily available for frequent and optimum use.

Of what use would a knowledge of the past practices and achievements and a detailed historical survey of the prior art of the chemical engineering unit operations be to chemical engineers? Would it merely furnish "interesting" and light reading or could it possibly advance the growth of our profession and increase our rate of production? Would the "return on the investment" be "attractive" in view of the time and effort that would be necessary for the collection and correlation of the available and essential information? Most chemical engineers can undoubtedly recall instances where waste of time and effort might easily have been avoided if a digest of the experiences of our predecessors had been readily available.

History credits Leonardo da Vinci with the invention of the wheelbarrow, with an early form of the hygrometer, and with the use of an extraction process for the recovery of lye from animal excreta, and a number of other truly chemical engineering applications. The first item is of interest to specialists in material transportation and to power engineers; the second to drying and air-conditioning specialists; and the third to those interested in extraction processes. Details of such items may or may not be of particular value to specialists in the design of new equipment and in the modification of existing designs of these types of equipment and devices. However, if they had been more generally known in the first hundred years after their invention and first use, our progress in these branches of engineering would undoubtedly have been much greater.

Many similar instances might be mentioned in connection with other unit operations which, if more generally known to the engineers and technical men after their first use, would have expedited considerably the progress of the unit operations. This is particularly true of such operations as distillation, crushing and grinding, flow of

THE PRIOR ART

NOWHERE IS THERE A BETTER GUIDE OR STIMULANT FOR CHEMICAL ENGINEERING DEVELOPMENT—WHETHER FOR PRODUCT OR FOR PROCESS

fluids, heat transmission, evaporation and crystallization. We now have available, in an unclassified and uncorrelated form, the experiences in many unit operations over several hundred years. We should be only too glad to make more readily available to ourselves the knowledge and experience that has been printed and is available in a number of isolated places by making a concerted effort to collect and systematize such information of the past. Is it not obvious that much might be gained by making these rich sources of experience and information more readily available and really useful?

It is freely admitted by many discoverers of "new" theories and laws, and by inventors of equipment, that their contributions, although real and valuable, are not radically new, but have resulted from a conscious or unconscious knowledge of the previous work in the particular field involved. A knowledge of the past art does not only serve as a store house or repository for older ideas, but it also serves as a useful guide and stimulant to imaginative and capable scientists and engineers. Contact with the printed art will certainly impart new ideas and guide our thoughts on the problems of the design, repair, and operation of chemical equipment and processes.

A great deal of time, money, and effort is wasted or gives inadequate return on the investment, due to such causes as the relative inaccessibility of a large part of the literature or the lack of appreciation of the value of the prior art. Much expense and duplication of effort may be avoided by the expenditure of a comparatively insignificant amount of time and money to acquaint oneself with the experiences and the recommendations of our predecessors.

The historical aspects of our profession are also of great importance from a legal point of view, both in respect to business law and to patent law. It is true that in these matters our safest general procedure is to enlist the aid and counsel of experienced lawyers skilled in these branches of the law. There are no really safe substitutes for such specialists. However, it is becoming increasingly important, especially to the chemical engineers intimately associated with industry, that they know at least some of the rudiments of business law and that they be quite familiar with patents and patent law. A great deal has also been said about the increasing com-

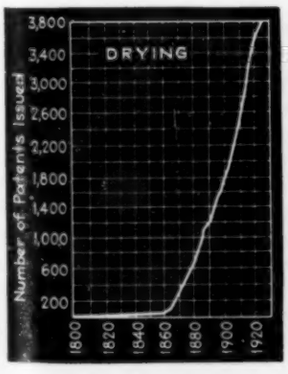


Fig. 2—United States patents related to drying

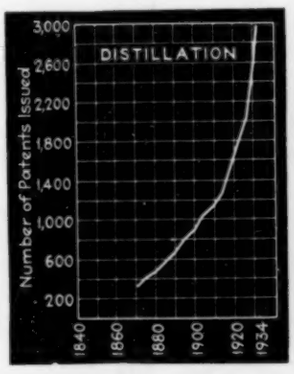


Fig. 3—United States patents related to distillation

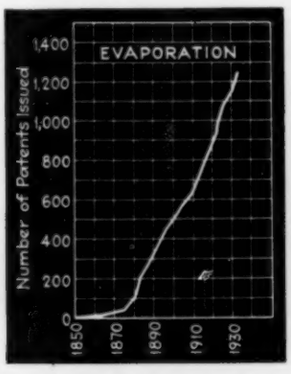


Fig. 4—United States patents related to evaporation

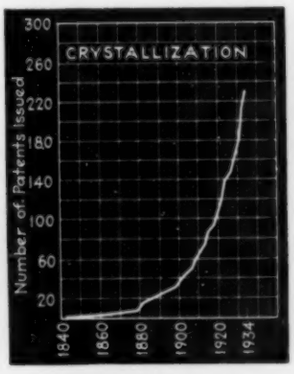


Fig. 5—United States patents related to crystallization

plexity of the patent situation, the growing difficulties in avoiding interferences with the prior art, and the decreasing confidence in the preparation and prosecution of a patent application.

A history of the patented art, giving a detailed account of the development of the individual unit operations with complete bibliographies and abstracts would be extremely valuable and should be a definite aid in relieving the present congested condition of the Patent Office. It should also increase the probable validity of the patents issued and should materially reduce the chance of interference with prior art. Thus, by making the older art of our profession more readily available the useless and unceasing litigation of patents would undoubtedly decrease, invention of new and valuable art would be accelerated and progress would be stimulated, with resulting saving of time, effort, and money now frequently wasted by duplication of effort. At this point it may be of interest to illustrate the antiquity, the rate of growth, and the large number of patents in a few of our unit operations issued in the United States. Figs. 2, 3, 4, and 5 show the number of U. S. patents that have been issued over slightly more than a century in the fields of drying, distillation, evaporation, and crystallization, respectively. Obviously, these graphs are merely indicative of the larger number issued in the other countries of the world.

A knowledge of the history of what might be called "man location" and a readjustment of the old, and in many cases perhaps current, lack of attention to a study of technical employees by employers to prevent them from remaining in positions for which they have little inclination or ability is of great importance. Proper attention should be paid to technical men during the first years after their graduation to give them a broad experience in their profession, thus enabling them to find the place most suitable to their talents and desires; such intelligent planning offers ample returns and should increase the value of the technical man to himself, to his employers, to his profession, and to the world. With such training of a technical man the problem of "man location," after his first few years in the active pursuit of his profession, should offer less difficulties than is now frequently the case. A great deal is being said about "job insurance." Most plans proposed belong to the therapeutic class of treatment; intelligent study, and application of the results of such study, to education, training, and experience of engineers should minimize the need of a dole in the form of job insurance and should increase the useful life and efficiency of future engineers. Such results are certainly possible and should command the immediate attention not only of educators but also of employers.

Fig. 6—Glass melting and blowing in Agricola's day

How can the history and the evolution of chemical engineering assist in this matter? Certainly the formal literature of the unit operations will be of little assistance in this respect. There is little history now available of the personnel problem in the engineering profession and, in particular, of the personnel problem of the chemical engineering profession. What is needed is a conscious effort on the part of the present living chemical engineers and their employers to go beyond the usual elements of the "Primer of Personnel" to formulate the principles of personnel as applied specifically to chemical engineers, and to lay the foundations for a coordinated literature and history of the most important part of our profession—the development and training of chemical engineers, an important part of which we choose to call "man location," as a parallel to that very important item of chemical engineering and industry in general—plant location. We develop machines, we develop processes, we study all and every product that man devises, but we almost completely neglect to study the technical man himself and how best to develop his efficiency.

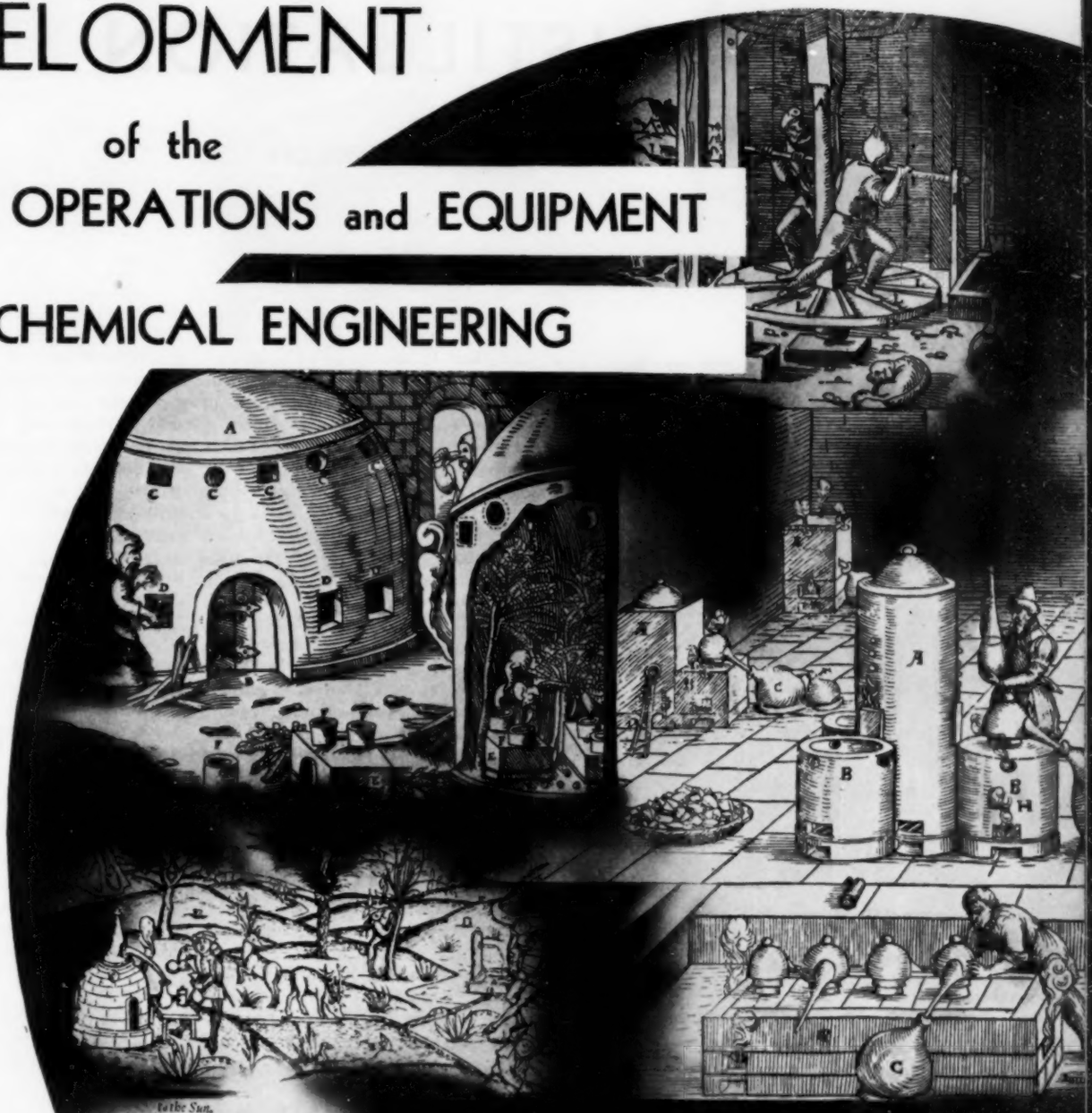
Another important subject to chemical engineers is "Safety"—the protection of himself and others from the hazards attending the handling of his working materials and the installation and operation of his equipment. Here again, our own experience and that of our associates and predecessors are our major guides in the warfare against industrial hazards. In spite of the growing interest in this work much still remains to be done, and the chemical engineer can furnish valuable assistance in the collection and correlation of existing information on the subject.

The rôle of the chemical engineer is many-sided and his position is strategic in the campaign for increased efficiency of chemical processes and chemical unit operations. There are many advantages inherent in such a strategic position, but there are also many responsibilities. The efficient chemical engineer must use every facility and tool available if he is to live up to and fulfill these responsibilities, and if he is to retain the advantages of his position. Not only must he "recognize, interpret, and apply the discoveries of science," but he must also take the more prosaic elements of well-known mechanical, thermal, and other physical laws, processes, and equipment and evolve new and more efficient tools.

There is still no substitute for experience; certainly there is no substitute for the combined experience of the many chemical engineers who have contributed to the literature of chemical engineering. Such experiences are invaluable histories. Let us recognize the benefits to be derived by making the prior art of our unit operations and related subjects more readily available and therefore more useful to our profession.

DEVELOPMENT

of the UNIT OPERATIONS and EQUIPMENT of CHEMICAL ENGINEERING



To trace the development of what today we call the unit operations of chemical engineering is not a task for any one man, nor can much of the early part be found in definite records. A fragment of wood or stone here, a bit of ancient writing there, have had largely to suffice for our contributors to the ensuing pages. Every science has added to the tools of our profession and early metallurgy much more than ancient chemistry. Our greatest debt, perhaps, is to Georgius Agricola and his "De Re Metallica," both for the record and for many of the delightful wood cuts reproduced in the articles that follow.

DISTILLATION

By GUSTAV EGLOFF

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Fig. 1—Still of the fourth century

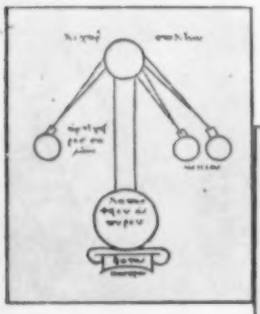


Fig. 2—Still of the eleventh century

Fig. 3—Tower taking off seven fractions

Fig. 4—Still with large reflux area, constant still head temperature and fractional condensation

DISTILLATION is perhaps the oldest art practiced by man, and its origin is lost in the mists of antiquity. From the records it is plain that the early workers understood, at least in part, many of the underlying principles which govern distillation today, but their application and their technique were crude and their operations of the simplest.

We do not know who the first distiller was, but history does tell that Aristotle in 350 B.C. discovered that by boiling salt water and condensing the steam he could recover fresh water and solid salt. Dioscorides, in the first century A.D., went Aristotle one better. He is the first man, so far as we know, to employ the principle of dephlegmation. He hung flock wool in the vapor stream over boiling liquids. The desired distillates were recovered by wringing the wool out, which was then returned to the vapor stream. The lighter vapors were presumably condensed and recovered. Thus, Dioscorides obtained several distilled liquids from his starting stock.

By the fourth century a considerable number of improvements had been made. Experimenters of that period developed a fairly good technique of distillation and the apparatus to carry it out. One form of fourth-century distillation apparatus is illustrated in Fig. 1, which shows a dome on top of the still for refluxing purposes. This dome is not vastly different from the domes of the shell stills used in petroleum refining until recently.

By the eleventh century a number of new features had been added. Fig. 2 represents an eleventh-century still which has not only a dome but also a column, which made it possible to recover three different fractions from the starting liquid. This apparatus did not differ so greatly from the aerial fractional condensers long used in the petroleum industry.

During the age of the alchemists improvements were numerous and important. The alchemists were able to take as many as six different fractions from a column simultaneously. They understood refluxing, control of still-head temperature (Figs. 4 and 5), reboiling of condensates (Fig. 6), preheating and continuous feeding of the liquid passing to the still while in operation (Fig. 4).

Fig. 3 shows a combination still and column equipped to take off six streams and bottoms simultaneously. Figs. 4 and 5 show methods for cooling of the still head. Stills of these types were in operation during the sixteenth and later centuries.

Porta, one of the early alchemists, was keenly alert to the importance of distillation. In 1553 he wrote as follows:

> "Now I am come to the arts and I shall begin from distillation, an invention of later times, a wonderful thing to be praised beyond the power of man; not that which the vulgar and unskillful men use, for they do but corrupt and destroy what is good; but that which is done by skillful artists.
>
> "This admirable art teacheth how to make spirits and sublime gross bodies, and how to condense and make spirits become gross bodies, and to draw forth of plants, minerals, stones and jewels, the strength of them that are involved and overwhelmed with great bulk, lying hid, as it were in their chests; and to make them more pure and thin and more noble, as not being content with their common condition, and to lift them up as high as heaven.
>
> "We can by chymical instruments, search out the vertues of plants and better than the ancients could do by testing them. What therefore could be thought

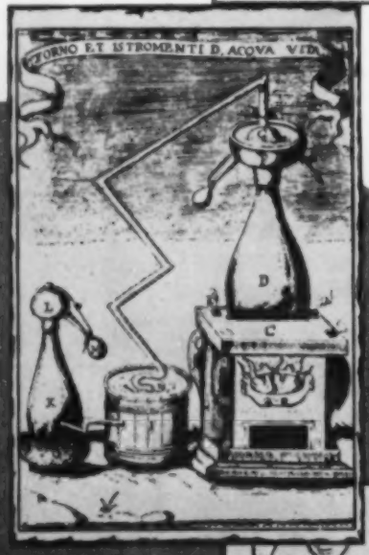


Fig. 6—Still with cooled head and preheater

Fig. 5—Still with reboilers

on that is greater? Let one that loves learning and to search nature's secrets, enter upon this; for a dull fellow will never attain to this art of distilling.

"Now we speak of oyls: these require the industry of a most ingenious artificer for many of the most excellent essences of things do remain in the oyl so close that without the greatest art, wit, cunning and pains they cannot be brought to light; so that the whole art of distillation dependeth on this."

He adds a further caution:

"If you distill common oyl, it will hardly run. You must be very careful that the ashes and pot do not wax too hot, for if the oyl within takes fire it will break the vessels and flie up, that it can hardly be quenched, and reach the very ceiling; so that it is best to operate upon oyls in arched rooms."

Appreciation of the potential economic value of distillation continued to grow. Worth, another alchemist, in 1692, stated in his work, "The Whole Art of Distillation." "This art is not rightly to be carried on without a considerable large fund, and when so managed will repay the owner or master with considerable interest."

All those engaged today in distilling liquids, whether they be in the wood-chemical, solvents, alcohol, benzol, petroleum, or other chemical industries, will readily subscribe to Worth's statement—at least the first part of it. Worth's vision of 243 years ago clearly foreshadowed some of the developments of today.

While we have made very creditable progress in the art of distillation who will be so bold as to say that we have not still as much to learn as Porta and Worth had in their day and that the further possibilities lying before us for discovery are not as vast as those that lay before the ancient alchemists? Research and development work are daily bringing clearer understanding of one phase or another of the distillation art, while flashes of new possibilities still farther in the future are occasionally glimpsed by the workers. Thus, accurate and useful knowledge is increased and guesswork is more and more being eliminated from the distillation art.

It is startling to observe that the beginners in the art of coal-tar refining and later in petroleum refining of our own day did not take full advantage of the principles of distillation which had been discovered and used by the ancients.

Distillation of coal tar, shale oil, and petroleum began in this country about 1850. The first stills for the purpose were cylindrical with capacities of three-quarters to 5 bbl. per day. From these small shell stills the early refiners, for reasons best known to themselves, went to the so-called "cheese box" design. The cheese-box still was mounted in a brick setting with numerous fire doors around the circumference, similar to an old-style brick kiln. No fractionating equipment was used with these stills, as the vapors were carried from the still dome through the vapor line direct to a water-cooled condenser. Some of the cheese-box stills were in operation less than twenty years ago (Fig. 9).

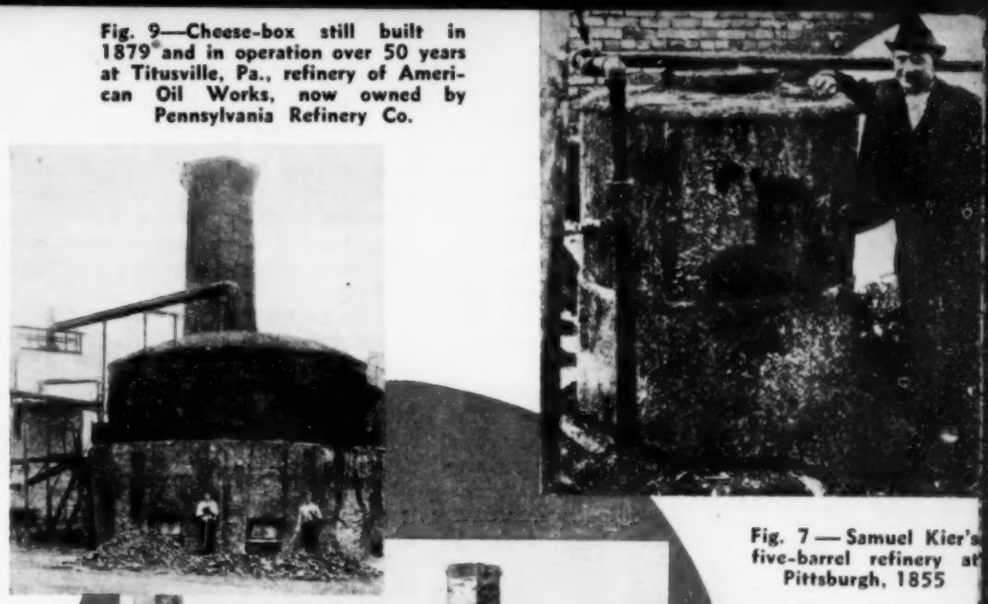


Fig. 9—Cheese-box still built in 1879 and in operation over 50 years at Titusville, Pa., refinery of American Oil Works, now owned by Pennsylvania Refinery Co.

Fig. 7 — Samuel Kier's five-barrel refinery at Pittsburgh, 1855

Fig. 8—One of the first refineries in Petrolia, Canada, 1870

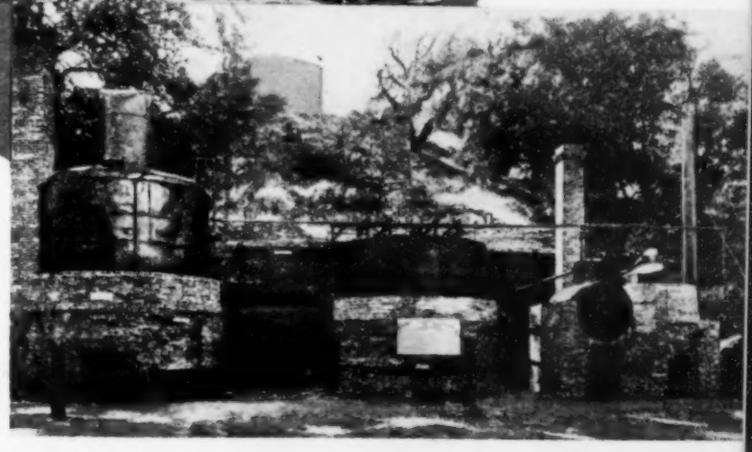


Fig. 10—First refinery at Newhall, Calif., built in 1876 by California Star Oil Works, later Standard Oil Co. of California

About 1885 refiners began to consider the possibility of continuous distilling operations. A development of great import in this connection was the placing of shell stills stepwise in batteries. Some of these batteries had a capacity as high as 5,000 bbl. a day. In operation, the crude oil was continuously pumped into the highest still in the battery.

The vapor stream from this first still was condensed into a light gasoline and the residue oil overflowed by gravity into still No. 2 and so on down the battery, some installations having as many as eleven stills. Heavy naphtha, kerosene, gas oil, and in some operations, wax distillate, were taken off in the intermediate stills and the heavy fuel oil or flux was continuously pumped from the end still in the battery. Not only did this arrangement make possible continuous operation, but to some extent it made up for the lack of fractionating equipment. The temperature increased progressively from still to still, and the quality of the streams was determined by their gravity. However, the fractionation was very crude and, in order to produce commercial products, it was necessary to redistill the various cuts and usually to treat them with chemicals.

Most of the redistillation was carried on in stills in the presence of steam, in order to lower the boiling point of the material. Fractionating towers were mounted on the steam stills. The first

of these towers were simply open pipe, or tank arrangements, for better fractionation. Later, overlapping baffle plates riveted or welded to the walls were used, and then packed towers were developed. All of these expedients were for the purpose of improving the fractions so as to reduce expensive redistillation operations.

The master development in petroleum technology was the pipe still. In this unit heat transfer was greatly improved and unit capacity increased enormously so that topping units were built with capacities of over 30,000 bbl. of crude oil a day. The purpose of these stills was to strip the gasoline and kerosene from the crude, leaving a fuel oil residue.

The next great development was the application of the bubble tower to petroleum fractionation. The bubble tower principle was borrowed from the alcohol and benzol arts. The combination of pipe still, flash distillation, and bubble tower marked a new and tremendously important advance in the petroleum industry.

With such a unit the oil was heated in the pipe still, whence it passed into a flash chamber, in many cases part of the tower, where as much as 93 per cent was flashed into vapor. The residue which collected in the bottom of the tower was pumped away as fuel oil. The vapors were passed to the bottom of the bubble tower there to be fractionated progressively into as many as nine streams.

This unit brought about great savings by eliminating a large part of the redistillation that had formerly been necessary. A number of the products today come from the fractionating tower in finished form to meet the specifications of the market.

Another type of modern distillation unit operates partly at atmospheric pressure and partly under vacuum. The largest unit of this type distills 14,000 bbl. a day of Mid-continent or East-Texas crude. In the atmospheric pressure phase it produces gasoline, naphtha, kerosene, and gas oil. In the vacuum phase, it produces heavy gas oil, two wax distillate cuts, overhead cylinder stock and asphalt flux. In this two-stage process 93 per cent of the crude oil is flashed into vapor and then separated into 9 fractions in bubble towers (Fig. 14).

Control of vapor pressure of motor fuels to suit the season is very important. It is accomplished by degassing the crude or by stabilization of the gasoline itself, whether straight-run or cracked, to remove hydrogen sulphide, methane, ethane, propane, and controlled quantities of butane. Fractionation has been so highly developed in the oil industry that methane, ethane, propane, butane, and pentane can be separated one from the other into desired purity.

If the distillation units of twenty-five years ago were in use today to refine the 893,000,000 bbl. of crude oil in 1934, the increased cost would be over $150,000,000 based upon increased fuel, labor, redistillation, chemicals, distillation unit costs, and losses.

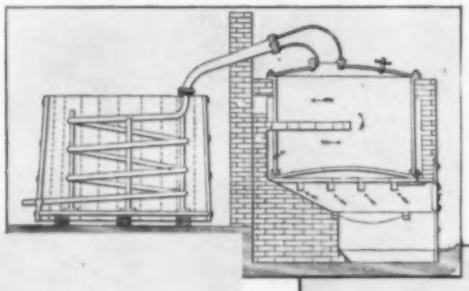


Fig. 11 — Cross-section of still and condenser used about 1865

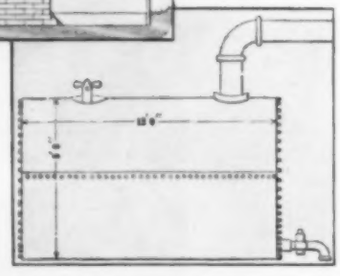


Fig. 12 — Petroleum still used in the early Sixties

Fig. 13 — Traveling refinery, moved from oil field to oil field by locomotive — In operation 1935

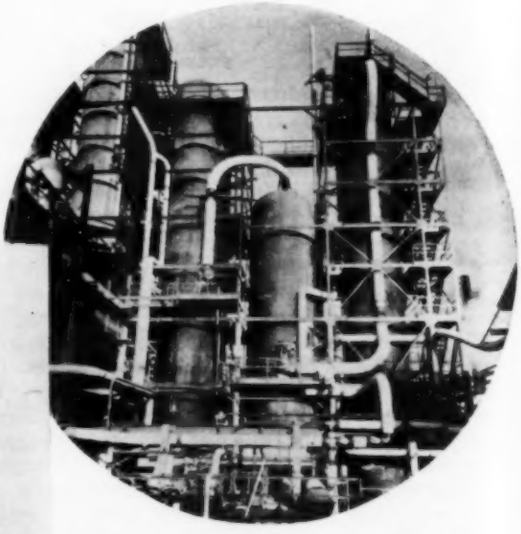


Fig. 15 — Cracking unit processing 19,000 bbl. per day

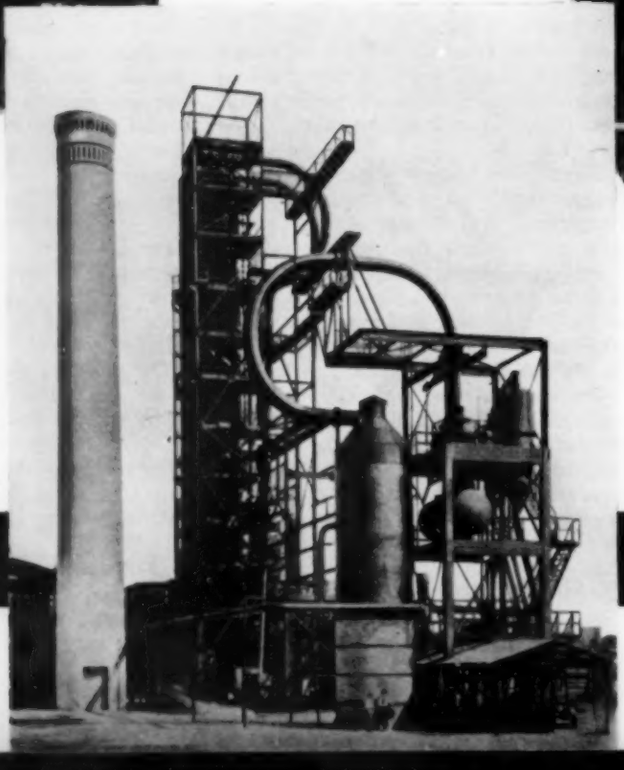


Fig. 14 — 10,000 bbl. Mid-continent 2-stage unit, atmospheric and vacuum distillation

FLOW OF FLUIDS

By W. L. BADGER

Professor of Chemical Engineering
University of Michigan
Ann Arbor, Mich.

FOUR WATER-ELEVATING MECHANISMS FROM AGRICOLA

Fig. 1, Upper Right—Manufacture of wood pipe and construction of a piston pump

Fig. 2, Right—Water-powered chain-and-bucket pump

Fig. 3 — Tread-mill-powered rag pump

Fig. 4, Extreme Right — Reversible, water-powered water hoist; note the ingenious means of controlling direction and speed of rotation of the double, overshot wheel

FLOW OF FLUIDS is always listed as one of the important operations of chemical engineering. However, it is fundamental also to all branches of engineering, and consequently it is not surprising that it can be traced to the very earliest times. In this article the flow and transportation of fluids will be discussed under two heads, namely: the channel for transporting the fluid and the device that produces the necessary head.

Pipe

The oldest piece of pipe on record is a hammered copper tube used for a drain from an altar in the tomb of King Sahuré of the Fifth Dynasty of Egypt. The Fifth Dynasty comes immediately after the pyramid builders in the Old Kingdom and is now generally placed at about 2900 B.C. This piece of pipe is about 40 in. long, 3½ in. in diameter, and was formed by hammering a sheet of copper around a mandrel. The joint was merely hammered shut and the pipe was installed with the joint on top. It is somewhat tapered as though several pieces had been joined together, but only one piece is now known.

Stoneware pipe was known throughout antiquity and was used by the Assyrians and Babylonians, and by the Greeks. It was also known by the race that occupied Crete before the rise of the Greek civilization. In the palace of Cnossos, which dates from some time in the third millenium, B.C., there have been discovered many features that are surprisingly modern. One of these is the existence of bath rooms and flush toilets supplied with water from rain water tanks on the roof. The pipe lines to and from these bath rooms were of glazed stoneware, with bell and spigot joints, concealed inside plumbing stacks.

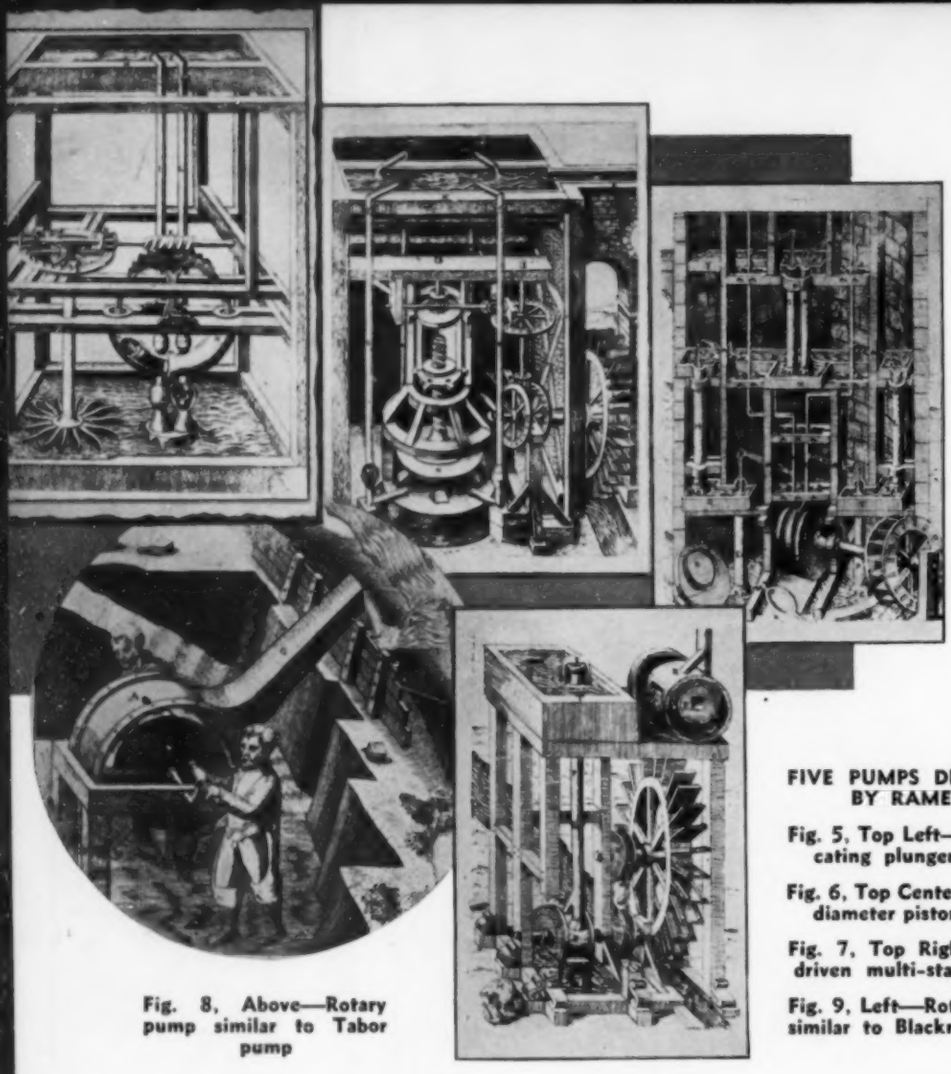
Stoneware pipe was in common use up to the beginning of the Dark Ages and many fine samples have been found in various places in Europe in the remains of late Roman villas.

The Romans used lead pipe to a very large extent. This was made by folding a lead sheet so that the cross-section of pipe was oval, and soldering the seam. Vitruvius, who wrote a handbook of architecture about 25 B.C., describes standard sizes and standard weights. The size of the pipe was the width of the sheet before it was folded over, and the weight of the sheet was standardized. He speaks of ten standard sizes ranging from 5 in. and weighing 60 lb., up to 100 in. weighing 1,200 lb.

Although the supply of water to the city of Rome came in through masonry aqueducts, the distribution of the water from the aqueducts to the point of consumption was almost entirely in lead pipe. The legal standard of quantity was the quantity of water that would flow through a pipe about 1 in. in diameter. It is curious that at this time the effect of head was not recognized. There was a suspicion that if the lead pipe were introduced at the bottom of the aqueduct it might take off more water than if introduced nearer the surface of the water, but the idea that the height from the aqueduct to the point of consumption had any thing to do with the discharge never occurred. In this same connection one commissioner of water works (who, although a political appointee, took his job quite seriously even to the extent of writing a treatise on it) reports that in his surveys of the aqueducts he discovered that on the average about one connection in three was illegal and represented water that was not paid for. Besides connections put in for individuals and charged to them, a certain number of connections ran to public fountains supplying free water.

The decline of civilization in the Dark Ages leaves a long stretch through which it is practically impossible to trace the history of the arts and engineering. As Europe emerges from the Dark Ages we find the use of wood pipe practically universal.

Agricola, in our Fig. 1, shows the method of making wood pipe. In the background is seen a log tied to a framework and a workman boring it out with a hand auger. Two of his augers lie on the ground beside him. It was necessary, of course, to make a relatively small hole first and then enlarge it. The augers used for the later cuts could not have a threaded point to draw them into the wood, and consequently the making of such pipe called for not only a great deal of skill, but a very great deal of strength. These wood pipe were always put together with a mor-



FIVE PUMPS DESCRIBED BY RAMELLI

Fig. 5, Top Left—Reciprocating plunger pump

Fig. 6, Top Center—Large-diameter piston pump

Fig. 7, Top Right—Cam-driven multi-stage pump

Fig. 8, Above—Rotary pump similar to Tabor pump

Fig. 9, Left—Rotary pump similar to Blackmer pump

tise-and-tenon joint, often reinforced with a metal band at the joint. The swelling of the wood when wet was sufficient to make the joint tight. This type of pipe was in common use until some time after the year 1800.

During the later Middle Ages occasional attempts were made to use metal pipe. Much lead pipe was laid in London but it was destroyed by the great fire of 1620 and was not replaced. Cast-iron pipe was first used in the latter part of the 17th century; and wrought iron pipe made by both the butt-weld and the lap-weld processes appeared between 1800 and 1830. Since this time the development of wrought iron and mild steel pipe, although improved mechanically, did not show any changes in basic methods of manufacture until the very recent introduction of electrically welded steel pipe.

The older works are particularly barren of any calculations regarding strength of materials or capacities of pipe. Carl Christian Langsdorf, in a book entitled "Beitrag zur Aufnahme der Salzwerkskunde," published in 1775, tried to develop a formula for the bursting strength of a tube. He was hampered by the fact that he did not know the tensile strength of any of his materials and therefore developed his formulas in comparative terms. He starts with the assumption that a lead pipe 12 in. in diameter with a wall ½ in. thick is safe for a head of 60 ft. of water. He also considers that if the strength of lead is 1, the strength of copper is 10.3, and the strength of iron is 15.5. On this basis he develops the formula

$$T = R\sqrt{\frac{2\,h\,pd\,(r + d/2)}{a\pi\,r^2}} + 1 - 1$$

where T = wall thickness of unknown pipe
R = inside radius of unknown pipe
h = safe working head for unknown pipe
π = strength of material in unknown pipe
d = wall thickness of known pipe
r = inside radius of known pipe
a = safe working head for known pipe
p = strength of material in known pipe

In the same way, for wood pipe he assumes that a pipe bored from a fir log so as to have a wall thickness of ½ in. and an inside diameter of 4 in. is safe for a head of 5 ft. of water. He assumes that if the tensile strength of fir is 1, that of alder is 1.66, oak 1.91, and beech 2.08. These may be substituted in the same formula.

He also gave the cost of the different types of wood per cubic foot and the cost of boring them per cubic foot. From this he calculated not only the cost of making the complete pipe but also the economical balance between the thinner wall possible with the harder woods on the one hand, and the increased cost of boring the harder woods on the other hand.

Pumps

The history of pumps is much more easily traced than that of pipe, because a pump was a machine that could be described. Although in very ancient times the lifting waterwheel and the well-sweep were used, in general water was rarely pumped and the engineer had to depend on finding a source of supply at such a level that it could be brought to the desired place by gravity. A cast-brass piston pump with metal valves has been found in Roman excavations but, in general, machines for lifting water were rarely used.

By the time of the later Middle Ages, engineering—and especially the written records of engineering—show a considerable development and from this time on, pumps of all types may be found. Agricola describes pumps, of course, because of their use in de-watering mines. Fig. 1 shows the construction of a piston pump operated by hand. The piston may be of metal (L or M) or it may be simply several layers of leather held between two washers. The cup leather, K, may be used in place of a piston, and N is a flap valve to be used on pistons. At the base of the pump at D is a foot valve.

Agricola shows several other pumps but most of them differ from Fig. 1 only in the arrangement of the motive power and not at all in the construction of the water-lifting mechanism. Two variations are those of Figs. 2 and 3 showing, respectively, a bucket elevator for water and a man-powered version of the familiar rag pump.

In Fig. 4 is another interesting method of raising water. Two leather buckets are alternately raised and lowered by a windlass driven by a water wheel. The wheel is an overshot wheel with two sets of buckets, each with its own spout from the forebay. Thus the operator in the pulpit can control the raising and lowering of the buckets by manipulating the levers controlling the flow of water to the spouts. The bucket in the center, apparently suspended from sky-hooks, is explained in the text as a

water-level indicator, and is to be understood as connected, by ropes and pulleys, to a float in the forebay.

Captain Agostino Ramelli was Chief Engineer of Louis XIV and to several other princes of his time. In 1570 he wrote a book on engineering entitled "Le Diverse et Artificiose Machine." This was published with parallel texts in Italian and French, but was later translated into several other languages. Several of the figures accompanying this article are taken from the German translation of 1620, in which of 195 copper plates, cut by Andreas Breitschneider, 130 are pumps or water-lifting devices of one sort or another. They contain single acting piston pumps differing only in the methods of operation, but these methods involve the widest variety of mechanical constructions.

It is curious that the double-acting piston pump does not appear until a great deal later. Ramelli, however, knew various kinds of rotary, positive-pressure pumps, corresponding to various types now on the market, and a variety of reciprocating devices that are no longer employed for lifting water. The mechanical means used for operating them show the widest variety of constructions. Although some are operated by a hand-turned crank, most of them are operated by water wheels, although occasionally a horse, a windmill, or a treadmill furnishes the supply of power. There is the most bewildering variety of arrangements of bevel gears, worms, cranks and cams to obtain desired motions.

Fig. 5 shows one of his peculiar pumps operated by a worm. It contains a device that Ramelli used many times for converting uniform rotary motion into reciprocating motion. The wheel, *B*, has teeth on only one-half of its circumference. As it rotates, these teeth first engage the pinion, *C*, and then the pinion, *D*, so that the worm, *E*, is rotated first in one direction and then in the other. This figure also shows clearly Ramelli's method of constructing pump valves. It should be remembered that this is long before the invention of the screw-cutting lathe, and all such worms as this were cut from timber by hand.

In Fig. 6 is a very large piston pump. Two wheels, *C* and *D*, each with teeth on one-half the circumference alternately engage the pinion, *F*, and thus give the worm on the horizontal shaft across the top of the cut a rotation first in one direction and then in the other. This worm rotates a sleeve that carries a nut, *M*, and the rotation of the sleeve in alternate directions causes the piston, *N*, to move up and down. The working barrel is so large that several suction valves, *P*, are employed and the construction of the discharge valves in the riser pipes is also shown.

Fig. 7 is interesting because of the use of cams, one of which is shown at *B*, to produce the reciprocating motion. This pump would be classified as a three-stage, single-acting, duplex pump. The mechanical rigidity of the main pitmans, *E* and *F*, would probably leave considerable to be desired. An interesting feature of this pump is the use of roller bearings, almost 300 years before Mr. Timken's time.

Early Rotary Pumps

In Figs. 8 and 9 are two remarkable rotary pumps, remarkable both for their simplicity of construction and drive, and because they are almost identical in principle with two pumps, the Taber and Blackmer, respectively, that are built today. Note particularly the detail of the rotary unit in the upper right of Fig. 9.

The rest of Ramelli's book contains mills of various types for grinding grain; saws for marble and wood; military devices, such as bridges for crossing moats, amphibian tanks, devices for pulling gates off their hinges, and even devices for sighting artillery when the target is not visible. This latter is also interesting in that it contains a gunsight with adjustment for both elevation and windage.

Except for refinement in details and the great changes in pump drive that followed the introduction of Newcomen's "atmospheric" engine (see Fig. 10) and the subsequent better engines made by Watt and others, there was really very little improvement in the construction of the reciprocating pump until Henry R. Worthington's invention of the direct-acting steam pump in 1840. This pump, shown in Fig. 11, operated by means of a steam cylinder directly connected to the pump cylinder, without the intervention of the cumbersome crank and flywheel previously used.

It was a single-cylinder pump, as the illustration indicates, and was displaced in 1857 by Worthington's next important invention, the duplex, direct-acting pump. Fig. 12 shows one of Worthington's early duplex pumps which was clearly very similar to the duplex pump of today.

A true centrifugal pump was very late in appearing, and the modern centrifugal pump is largely the work of the Sulzer brothers, around 1890.

In general, then, it would appear that with the exception of the true centrifugal pump, almost every pumping device we now have, was known in the 16th century. We no longer have to depend on undershot water wheels or direct man power, we make our parts of metal instead of wood, and we have machine tools to increase precision in construction, but we have very few principles of operation except those that were well enough known to be in a standard handbook before 1600.

STEPS IN EVOLUTION OF STEAM PUMP

Fig. 10, Right — French adaptation of Newcomen's "atmospheric" steam pump, about 1750

Fig. 11, Below — First direct-acting steam pump, Worthington's invention of 1840

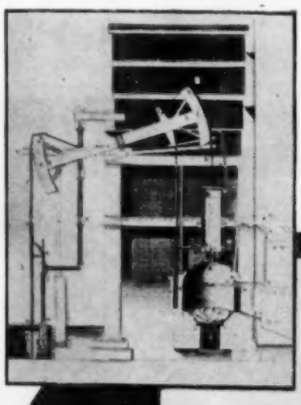


Fig. 12, Below — Early Worthington duplex, direct-acting pump, similar to those of today

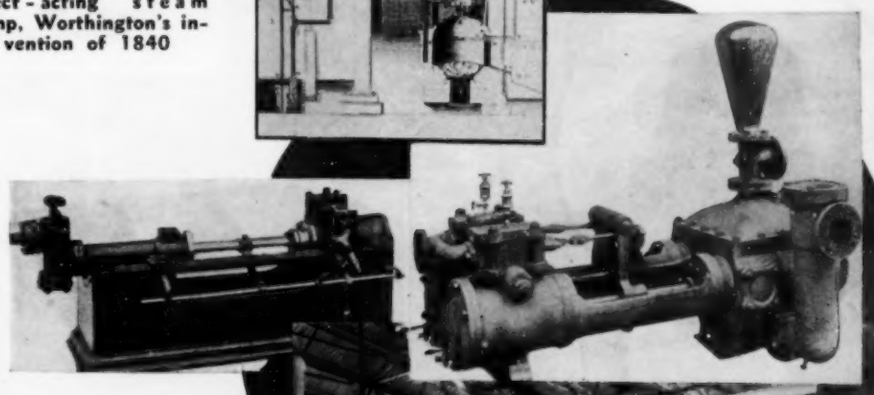


Fig. 13, Right — Worthington Hivol pumps of 1935 in a refinery

CRUSHING AND GRINDING

By S. B. KANOWITZ

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AMONG the operations used in the chemical industry, that of crushing, grinding and pulverizing has had the longest continuous existence. The process of converting wheat and other grains into flour dates back to prehistoric times. Primeval man pounded his grain with a hand stone, but did not rub or roll it. For 4,000 years this was the only form of mill in use. Fig. 1 shows a typical example.

Fig. 1—Grinding grain, 500 B.C., from vase in Berlin museum

The first grinding mill was the saddle stone. The Greeks and Romans knew it and it is still in use in many districts. This marked the first change from an impact or hammering action to a rubbing or grinding action; the upper surface of the stone was made concave. In this hollow the material was ground with another stone which was worked forward and backward, not rolled. This method of grinding, in use in the time of Abraham, is used by the native Africans of today.

The saddle stone endured through the time of the Chaldeans (about 4,000 B.C.) to the time of the civilization of Greece and Rome. In the Americas the aboriginal inhabitants were saddle stone millers and their relics attest that their mills were greatly superior to even the best saddle stones in Europe.

The low efficiency of these several contrivances created a desire for further improvements and so the hand mill or quern was developed. Here a circular motion was introduced. There is evidence of the existence of this mill among almost all the peoples of antiquity. Thus we read in the Bible (Deuteronomy XXIV:6): "No man shall take the upper or lower millstone to pledge."

A Roman hand mill is shown in Fig. 2. Originally it consisted of two stones, the lower fixed and the upper revolving. At first the upper stone was lifted off when fresh grain had to be added. Later, however, it was made with a hole in the center while the lower had a projection which passed through this hole. Between this pivot and the hole enough space remained for adding grain. A grip was added to the upper stone so that it could be turned more easily. The quern in a more highly developed state, as a complete grinding machine in which the parts were mechanically combined, was invented in Italy about 300 B.C. Fig. 3 shows a milling establishment recently uncovered in Pompeii. Another early but important improvement in the quern was the grooving of all the grinding faces of the stone. The edges of the grooves performed the grinding and their hollows conveyed the ground product to the rim of the stones. This type of quern is still found in parts of Europe and Asia and is used quite extensively in China and Japan.

Figs. 2 and 3—Roman hand mill and group of querns uncovered in Pompeii

Fig. 4—Italian mills of about 1400 shown by Biringuccio

Figs. 5 and 6—Mills described by Agricola including hand- and goat-powered millstones and water-powered stamps

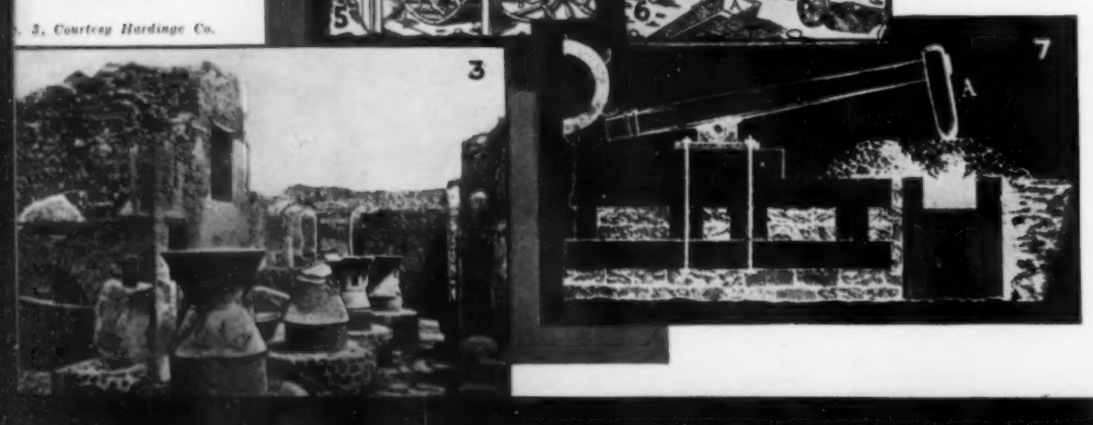


Fig. 7—Early power hammer for breaking hard materials

Advent of Water Power

With the exception of the development of the stamp mill (Fig. 6) in early metallurgical practice there was, after this, very little advance in milling machinery for about 1,800 years. True, there was a change in the motive power but practically no new designs were developed until well after the advent of the steam power age. Originally the woman was the universal miller and supplied the power which drove the

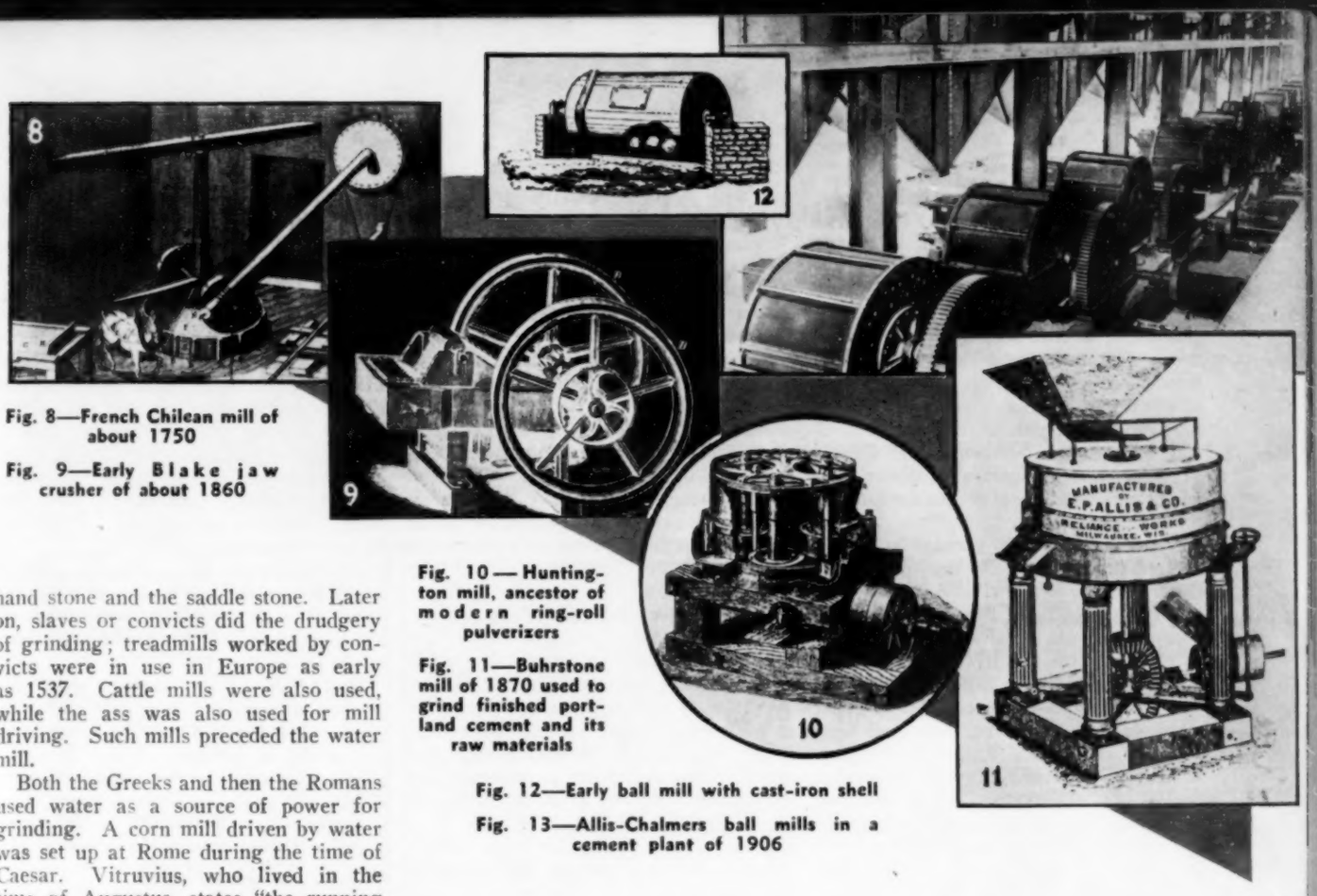


Fig. 8—French Chilean mill of about 1750

Fig. 9—Early Blake jaw crusher of about 1860

Fig. 10 — Huntington mill, ancestor of modern ring-roll pulverizers

Fig. 11—Buhrstone mill of 1870 used to grind finished portland cement and its raw materials

Fig. 12—Early ball mill with cast-iron shell

Fig. 13—Allis-Chalmers ball mills in a cement plant of 1906

hand stone and the saddle stone. Later on, slaves or convicts did the drudgery of grinding; treadmills worked by convicts were in use in Europe as early as 1537. Cattle mills were also used, while the ass was also used for mill driving. Such mills preceded the water mill.

Both the Greeks and then the Romans used water as a source of power for grinding. A corn mill driven by water was set up at Rome during the time of Caesar. Vitruvius, who lived in the time of Augustus, states "the running stone was supported on the end of an upright shaft which served also as the axis of a flat toothed wheel." This latter worked in another, fixed at the upper end of the great axis, to the lower end of which was fastened the horizontal water wheel.

The windmill came into use much later than the water wheel; the year 1200 seems to be about the date for its introduction in England. About 1780, or nearly 600 years later, steam power was first utilized in London for driving millstones; by this time the stones had become flat and round and were scientifically furrowed. They ran close together and in general resembled the modern buhrstone mill in their operation.

Thus at the advent of the American chemical industry the stone mill was practically the only type of grinding mill in existence. Although Agostino Ramelli, in 1588, published the design for a mill employing a corrugated iron roll, it had to wait for the steam engine before it could become commercially feasible. Up to the middle of the 19th century crushing of raw materials such as rock and ores was still largely accomplished by hand hammers. An early power-driven hammer for breaking hard materials is shown in Fig. 7.

The illustration in Fig. 8 shows an old style horse-driven Chilean mill of about 1750. A millstone is laid flat on the ground and fastened in place. To the revolving upright shaft are fastened one or two grindstones which revolve about their axis and at the same time move round with the shaft. This mill produced a moderately fine product particularly when it ground wet. In modified form this type is still used.

Modern Mills

By this time Cornish rolls had been introduced for crushing, but it was not until the introduction of the jaw crusher that ores and minerals of large sizes could be handled in large quantities. In 1858 a patent was granted to Eli Whitney Blake for the jaw crusher, known as the Blake crusher. An early model of this crusher, lever pattern, is shown in Fig. 9. The general design of the Blake crusher remains the same today, with certain modifications in details.

A similar crusher, the Dodge, has the movable jaw pivoted at the bottom, but otherwise it employs the same principle as the Blake.

The gyratory crusher came next. This type is now manufactured in sizes capable of handling thousands of tons of rock per hour. As the jaw and gyratory are primarily coarse crushers, the hammer mill, ball mill, and rolls were developed for the production of a finer and more uniform product. Cast metal rolls were first tried out about 1750 but did not come into general use until over one hundred years later.

The first practical hammer mill, with rotating shaft to which were fastened fixed hammers, came into use about 1870. From this early type was evolved the present mill which may be equipped with many rows of fixed or pivoted hammers, in sizes capable of crushing nearly a thousand tons of stone per hour. When it came to the grinding of various materials stone mills were still practically in universal use.

A modification of the old Cornish or crushing rolls was developed into the present roller mill used in flour milling; it was later borrowed by the chemical and metallurgical industries for fine grinding, particularly when a fine granule was required with a minimum amount of powder. On account of the low output the roller mill was not very well suited for grinding minerals and chemicals; where a very fine product was required considerable bolting was necessary. A different type, the ring-roll mill, was developed to overcome these disadvantages. These mills were built with stationary grinding rings on the internal surface of which rotated rolls. In some of these units the ring was made to rotate. One of the early mills of this type, the Huntington mill, is illustrated in Fig. 10. In its early form it was used for wet grinding. A later development made dry grinding possible. The pulverized dry material or the pulp was discharged through a screen which was situated above the grinding ring.

From the Huntington mill were developed the Bradley, Griffin, and Raymond roller mills with screen and with air separation. The Kent and Sturtevant mills are ring roll mills in

which the grinding ring revolves in a vertical plane; they also have three rolls mounted on horizontal shafts, pressing against the rotating ring. Where fine grinding is required the latter mills are now being operated in closed circuit with screens or air separators. The roller mill with air separation has been developed to a point where it can grind extremely fine. Drying, cooling or dehydrating of a material can now be accomplished during grinding, and an inert atmosphere may be maintained to prevent combustion or explosion.

The hammer mill surrounded by a screen through which the pulverized material is driven was and is still used for fine grinding. Formerly the discharge was nearly always screened or bolted, but with the present high speeds and with extremely fine screens surrounding the mills it is possible to grind many chemicals, colors, dyes, and food products directly to a finished product.

An early type of ball mill is illustrated in Fig. 12. It consisted of a cast iron barrel, 2-3 ft. in diameter and up to 5 ft. long. As grinding medium, cast iron balls or short cylinders were used, each weighing 30-60 lb. From this type of mill was developed the present large compartment tube mills and conical mills. Fig. 14 illustrates a Hardinge conical mill equipped with integral air separation. The tube and the conical mills are used extensively in closed circuit with hydraulic classifiers and with air separators.

A ball mill which was the forerunner of certain types of mill used at present is illustrated in Fig. 15. *A* is a heavy saucer-shaped receptacle connected to the vertical shaft, *B*. Above the saucer is a disk, *C*, equipped with four recesses in which are four 32-lb. cannon balls, resting on the saucer below. The disk revolves in a direction opposite to that of the shaft, *B*. Wear on the disk is prevented by the steel pins, *F*. The idea of this design was to have the heavier particles move to the periphery, while the finer particles go towards the center where they are discharged.

Ball-and-Race Mills

In 1850 the so-called Cochran's quartz crusher was placed on the market. This was a mill with balls rotating in a horizontal plane. These balls consisted of a ring of alternating large and small balls, placed on a rotating disk or saucer. On top of these balls was placed another saucer, inverted. In a general way the assembly was similar to the race of a modern ball bearing. The purpose of the smaller balls was merely to keep the larger balls apart. The material was fed through the center of the upper grinding ring, or saucer, passing down between the balls where it was crushed and discharged through the bottom. The Fuller and the Babcock and Wilcox mills are the latest developments of these types of ball mill. For the purposes of comparison it is interesting to note that the original 33-in. Fuller mill ground 2½ tons of coal per hour while the latest 82-in. air-swept B. & W. mill produces 54 tons per hour. When grinding rock the 60-in. B. & W. mill operating in closed circuit with an air separator, grinds 38 tons of rock, against 2 tons produced by the old 33-in. screen type. A similar setup used for grinding cement clinker produced 18 tons per hour, compared with 2 tons for the old 42-in. screen-type Fuller mill.

Air separation as an integral part of a mill first came into use about 50 years ago. One of the early applications of air separation to a Raymond pulverizer is shown in Fig. 16.

Ball mills, of the various types described above, and ring-roll mills do most of the fine pulverizing throughout the world at present. They have increased in size to the point where a single mill now can produce more than a battery of mills did 20 to 25 years ago. Many refinements have been made in their design and, due to the great development in the various alloys, the life of the wearing parts has been greatly increased. It is also possible to build a grinding system that will withstand the corrosive action of many chemicals.

The most recent development in hammer mills is the application of air separation for regulating the fineness of the finished product. Hot air or flue gases may be introduced to remove moisture from the material being pulverized. Still more recent is the Hadsel mill, shown in Fig. 17, which has just emerged from the development stage, with its seventh installation completed in the metallurgical field.

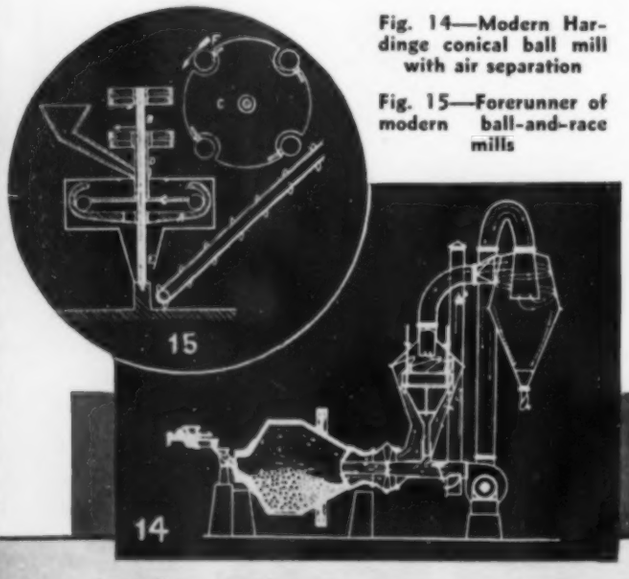
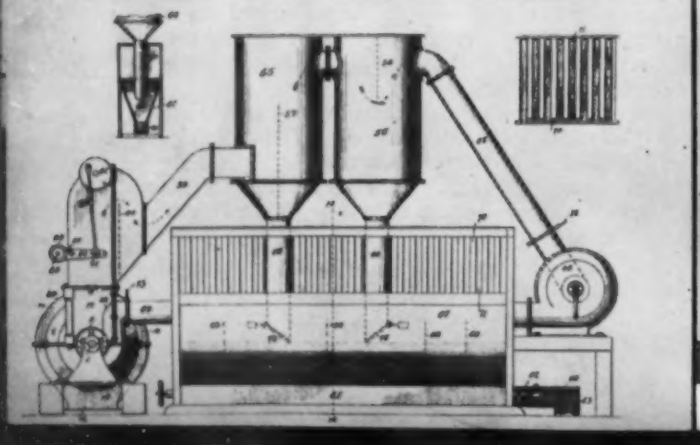


Fig. 14—Modern Hardinge conical ball mill with air separation

Fig. 15—Forerunner of modern ball-and-race mills



Figs. 16 and 17—Early Raymond air-separation mills, the first from a patent specification of 1888, the latter, of 1892

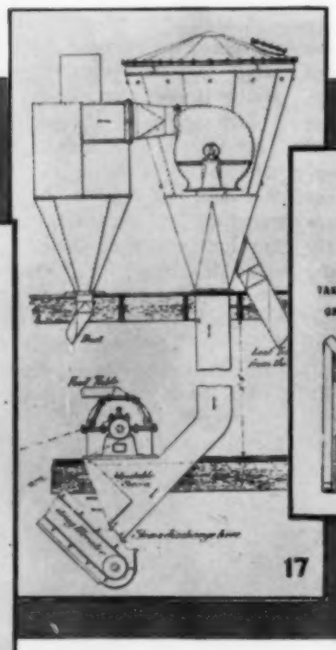
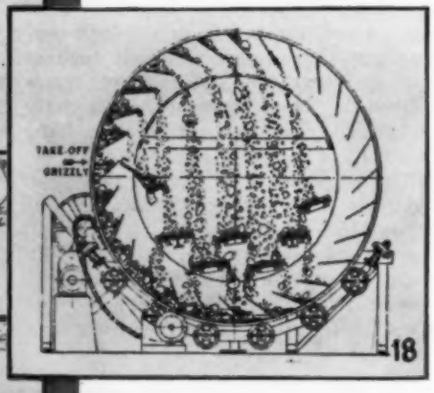


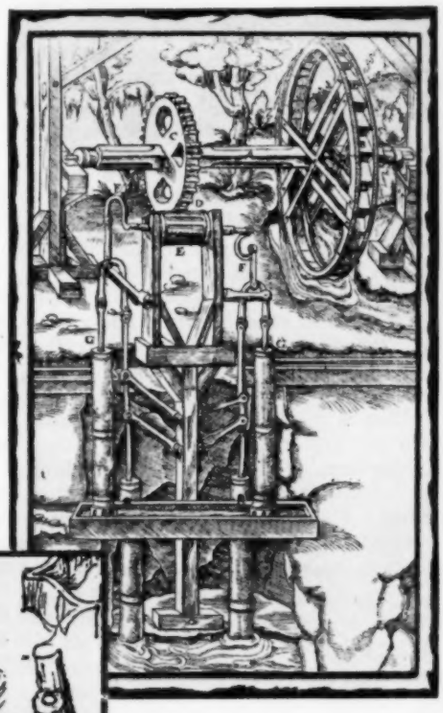
Fig. 18—Hadsel mill (Hardinge), the latest development in metallurgical crushing and grinding



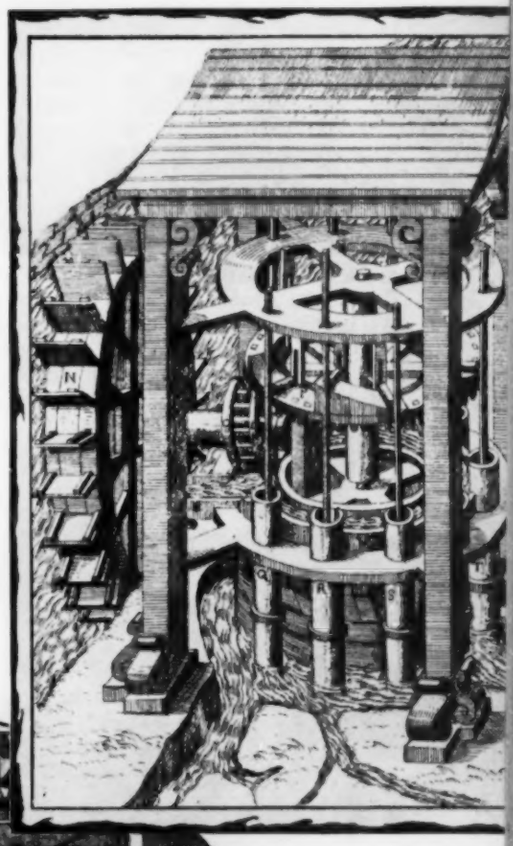
Mechanical Ingenuities of Early Engineers

Herewith we offer as good evidence that inventive genius is no recent discovery a number of examples of power generation and transmission for which Renaissance and early modern engineers were responsible

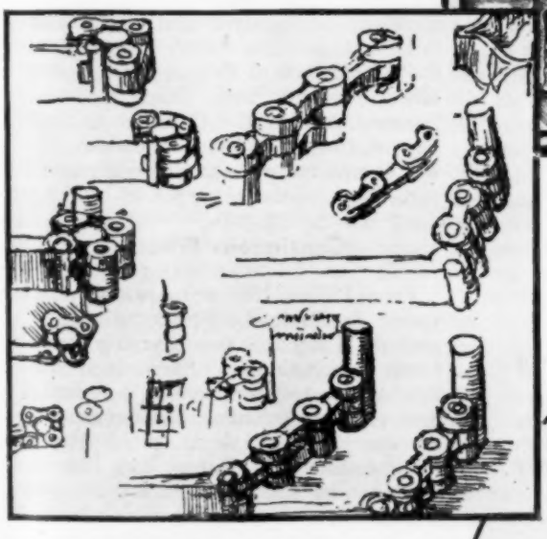
Branca's impulse turbine of 1629, although a more artistic conception than its descendant, is the direct ancestor of De Laval's modern turbine of 1882 (After Moyer, "Steam Turbines")



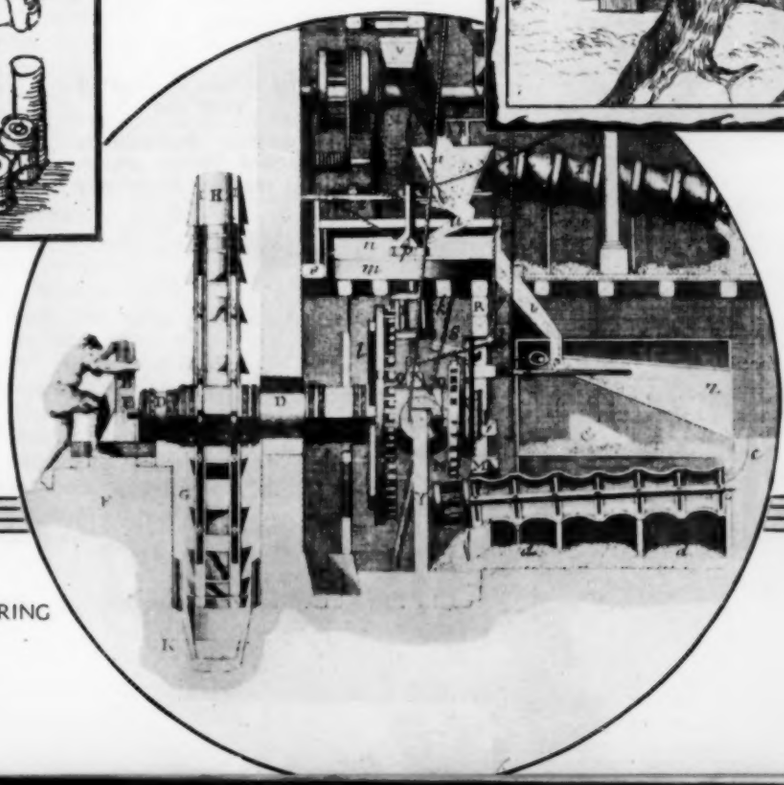
Multistage pumping held no terrors for Agricola as this two-stage duplex model of 1550 will demonstrate



This combination of water power, cams and piston pumps is only one of a hundred equally ingenious designs of Capt. Ramelli, chief engineer to Louis XIV



Leonardo da Vinci's drive chains of about 1500 were as much ahead of their time as most of his other amazing inventions (After Feldhaus, "Leonardo")

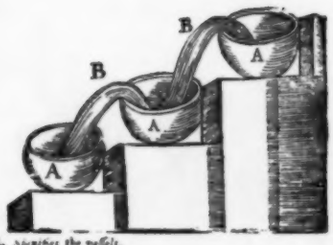


And here is power eration and trans sion in a French m 1750, complete gearing and rope

FILTRATION

By EDWIN LETTS OLIVER

President, Oliver United Filters Inc.
San Francisco, Calif.



A, *signifies the veſſels.*
B, *The ſtreds.*

Note that the ſtreds muſt be firſt wet in fair water, and the feculent matter be put into the uppermoſt veſſell.

Note alſo whereas here be two receivers, that in many caſes one may be ſufficient.

This way ſerves for the purifying of decoctions, juices, or diſſolutions of ſalts from their feculency, for that which is diſtilled by the ſtreds is as clear as Cryſtall, when what remains is very feculent.

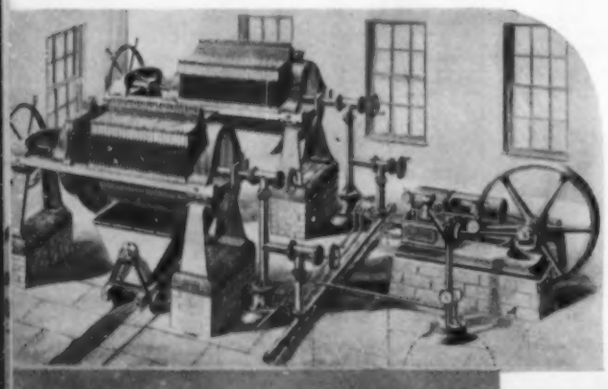
How John French described capillary filtration in his book, "The Art of Distillation"

FILTRATION in its earliest forms is as old as history itself. It was undoubtedly employed very crudely many centuries before the dawn of civilization and references to its use, in the manufacture of wine, have been discovered in very early literature. For instance, the capillary filtration of liquors by means of siphoning through threads has been recorded on the tomb of Rameses II, at Thebes. Although it is not specifically mentioned, filtration was probably used by the Chinese in the manufacture of wine as early as 2000 B.C. Plato referred to capillary siphoning as early as 400 B.C. Wine filters employed in Egypt, China and Rome consisted in fabric bags, while the ancient Romans also used strainers made of silver, bronze or linen or other fabrics. Filtration was described by Geber, the Arabian, in the 8th century. As in the case of other early writers on filtration, he distinguished between two kinds, capillary siphoning through threads and ordinary filtration employing the resistance of some sort of membrane or sand to hold back the non-filterable particles. The former process was much used until recent times, perhaps as late as the middle of the 19th century, when it finally died out because of its slow action and limited application.

Filtration was used by the ancients principally for the clarification of water and wine. It was early discovered that both sand and charcoal are good filter mediums and these appear to have been considerably employed. Other early gravity filters consisted of false-bottomed boxes lined with fabric or paper. For capillary siphoning threads of cotton and wool seem generally to have been employed. The alchemists relied principally on sand filtration and capillary siphoning, although reference to the use of paper as a filtering medium has been discovered in their writings.

What is generally considered to have been the first filter press patent is that of Needham, in England, in 1828. Bag filters were extensively employed at this period. They were, however, slow and required frequent cleaning. In order to increase the rate of flow, Kite in England, in 1857, devised the method of forcing liquid through the bags by means of a pump. In the period from 1850 on, rapid development in filter mediums was made with such materials as asbestos, gun cotton, powdered glass, and other special substances coming into use.

It was at about this time, in 1869, that Bunsen perfected the first practicable suction filter. Numerous attempts had previously been made to filter by vacuum, but this seems to have been the first successful application. Gooch followed shortly with his crucible type filter and suction type filter tanks with false bottoms were shortly employed in the potash beds of France. The heavy labor required with these methods, however, turned the thoughts of inventors toward continuous vacuum filtration and toward semi-automatic pressure filters of various types.



Filter presses of about 50 years ago

Modern hydraulically operated Shriver presses in a vegetable oil refinery

Continuous Filters

From 1870 to 1896 many patents were issued in England, France, Germany and the United States covering many forms of continuous filters including several types which have only recently been made a mechanical and commercial success. For example, these old patents disclose continuous filters with drums having filter cloth on the outside; on the inside; and with cloth which leaves the drum and passes over rolls for drying the cake and cleaning the cloth. These patents also disclose filters covered with hot-air hoods and filters on which granular solids are fed to the top of the drum. However, strange as it may seem, the history of industrial operations does not disclose that any of these patented filters were ever put into extensive practical operation, if indeed they were ever operated at all. Possibly the inventors of these filters were so far ahead of industrial development that

commercial exploitation was not warranted.

It was not until 1896 that the Solvay Co. put into successful operation a continuous drum filter for washing and partially drying bicarbonate of soda in soda ash manufacture. This filter consisted of a heavy, simply constructed cast-iron drum, covered with wool cloth and partially immersed in a tank filled with material to be filtered. Vacuum, applied through a hollow trunnion, caused the cake to form on the surface and this in turn was removed by a scraper.

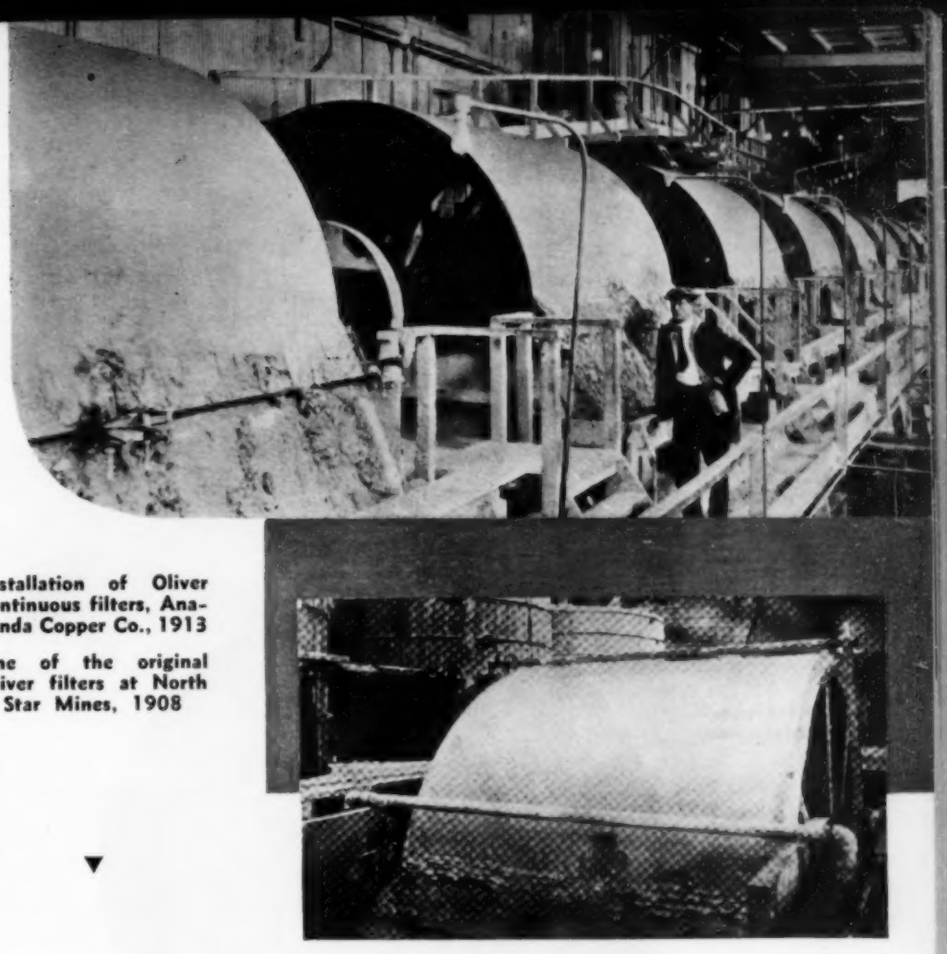
Moore Leaf Filter

The next significant development in vacuum filtration which became an operating success appears to have been that of George Moore, in 1903, who built a "basket" of ribbed wooden filter leaves, covered with cloth and connected to a source of vacuum. The basket was handled by an overhead crane and lowered into a tank containing cyanide slime. After cake formation the basket of leaves was raised out of the pulp tank and then lowered into a barren wash solution tank from which it was transferred to a wash water tank. After completion of the wash the basket was raised and traversed by the crane over a dump hopper, into which the cake was discharged by air pressure. The first installation at the Golden Gate Mill at Mercur, Utah, was the forerunner of many successful plants throughout the world utilizing the basic Moore principle.

A few years after Moore started filters at the Golden Gate Mill, a plant was installed at the Lundberg, Dorr and Wilson Mine at Terry, S. D., which contained many improvements and was used successfully throughout the life of the mine. This plant was followed by numerous successful Moore filter plants in other countries.

Soon after George Moore had made a practical success of his filter, Charles Butters modified the construction and operation by making the leaf assemblies non-removable from the pulp tank except for purposes of repair. Butters' *modus operandi* was to transfer the pulp, the wash solution and the wash water from the tank to other tanks, rather than to transfer the leaves. This made a much larger unit practical than was possible with the Moore filter, and many successful Butters plants are still in use throughout the world. After many years of patent litigation the Federal court held that the operation of the Butters filter infringed the Moore process patent.

The Moore leaf filter seems to have been the inspiration for a number of others in addition to the Butters. One of Moore's associates, David Kelly, mounted filter leaves on a removable carriage which was placed inside of a steel container, into which the pulp to be filtered was introduced under pressure. A few filters of this type were used in metallurgical plants, but the widest use for the Kelly filter has been in beet and cane sugar factories and in oil refineries.



Installation of Oliver continuous filters, Anaconda Copper Co., 1913

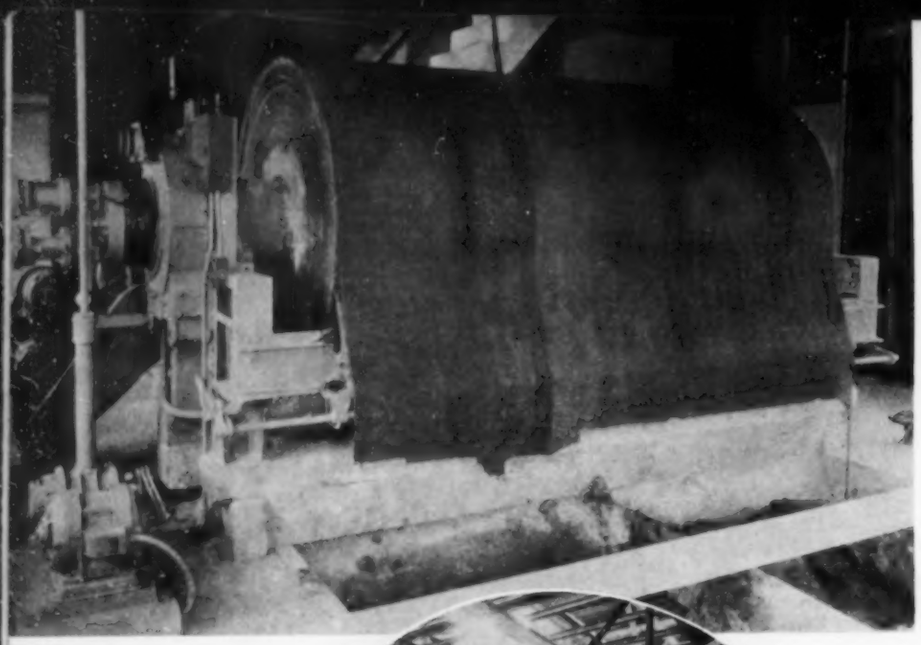
One of the original Oliver filters at North Star Mines, 1908

In 1907, E. J. Sweetland invented the clam-shell filter with circular leaves, in which the leaves are fixed in the upper portion of the clam-shell. Cake is formed under pressure and is discharged either by automatically sluicing the cake into the lower portion of the shell, from which it is removed by a scroll, or the cake may be discharged after the clam-shell is opened, by a reversal of pressure, which drops the relatively dry cake into a hopper. The Sweetland filter is in extensive use throughout the world in beet and cane sugar factories, oil refineries and chemical works.

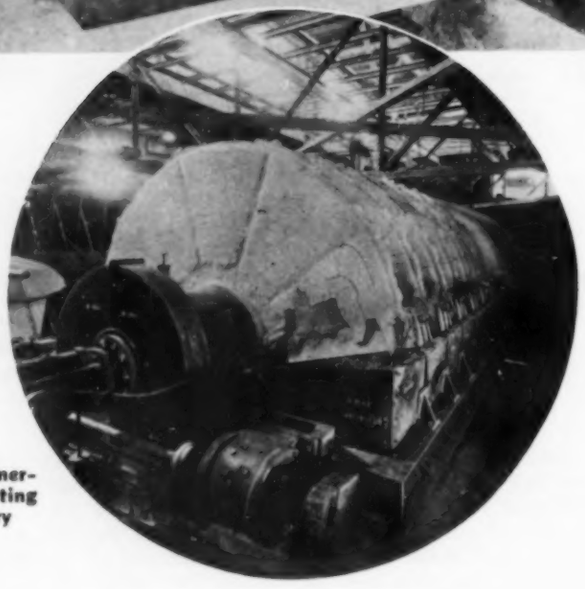
In about 1910, C. W. Merrill introduced his combined leaching and sluicing filter press in the cyanide plant of the Homestake Mine at Lead, S. D., where filters of this type have been in successful operation ever since. This Merrill plate and frame press is well adapted to special types of ore, but has not been extensively used either in the metallurgical field or in other industries.

Dr. H. S. Hele-Shaw, an inventor of several well known devices, during 1922 developed a very unique process of edge filtration through packs of paper. This principle of filtration is quite unique and differs from all the filters previously described in that filtration does not take place through filter membrane, but is effected on or close to the edge of a stack of paper disks compressed at about 80 lb. pressure. This "stream-line" filter produces ultra clarity of the filtrate, so that it is particularly well adapted to the clarification of lubricating oils, cordials and liquids requiring extreme brilliancy. This filter is also used for removal of sludge and water from transformer oils, being operated as a vacuum filter in the latter case.

To get back to the rotary type of vacuum filter, the first continuous filter type to be successfully introduced to the metallurgical industry was developed at the North Star Mines, Grass Valley, Calif., by the writer in 1907. The drum of this filter is divided peripherally into a number of segmental compartments, each of which in turn is connected through pipes which extend out through the drum trunnion to a multiple-ported valve, which in turn is connected to sources of vacuum and compressed air. The automatic valve which controls the various steps in the cycle can be so constructed that it will separate the filtrate into two, and in



Oliver filter for recovery of industrial wastes



Installation of American filters operating on cement slurry

some instances, into three, portions, with different degrees of vacuum, if necessary, affecting each of the different filtrates. Thus it becomes possible not only to filter and wash the cake continuously, but to separate the filtrate and wash solutions. One of the vitally important features of this filter, and probably the one which was most responsible for making it an operating success, is the spiral wire winding which protects the filter cover from injury by the scraper. The basic features incorporated in the original design are still in use in Oliver continuous filters used by the metallurgical industry, but many modifications of the basic design have been introduced to better adapt this filter to other requirements, as for example in the pulp and paper industry where the cake or sheet is removed by a vacuum discharger or by driven rolls, instead of by a scraper. Another modification is the so-called top-feed filter in which crystalline salts are fed to the top of the drum and discharged by the use of scrapers after a revolution of 270 deg., there being no tank used in which to submerge the drum. By hooding the top-feed filter and introducing large volumes of hot air the salt can be reduced to almost complete dryness.

The Feinc filter, which was developed by Arthur Wright and Frank W. Young in 1923, differs chiefly from other drum type filters in that the discharge of the cake is effected by a system of endless strings passing around the drum, and over a series of rollers. In some instances the strings are run over a steam-heated drum for drying the cake before discharge. A modification of the Feinc filter is the substitution of a woven wire endless mat, which passes around the drum, the cake being formed in the meshes of the wire mat. This wire mat is carried from the drum over a series of rollers and festooned by a very ingenious method inside of a heated dry house. At the end of the travel the wire mat is vibrated to discharge the cake and the cleaned mat continuously returns to the filter tank.

Still another principle of continuous drum filtration is incorporated in the Dorrco filter which was introduced at the Chino Mines, Hurley, N. M., in 1925 by John T. Shimmin. In the Dorrco filter the filter cloth is fastened on the inside of the drum in panels over each of the compartments, these compartments being connected by piping to an automatic valve and to a pulsating air blowing device which virtually shakes the cloth to free it from the cake at its uppermost position. An important factor in this method of operation is that gravity operates in the same direction as the vacuum and assists in cake formation. Any coarse particles in the pulp, of course, settle out on the filter cloth, thereby aiding rather than hindering filtration. Ill effects from the segregation of the heavy solids which sometimes cause trouble in other types of drum filter are avoided.

The continuous rotating disk filter, now known as the American, was introduced by Al Genter in 1917. Instead of a drum, a number of filter disks made up of removable sectors are mounted on a horizontal shaft which is divided into compartments to correspond to the sectors. On the end of the shaft is a multiple-ported valve to control the various steps in the filter cycle. The disks are partially immersed in a tank containing the pulp to be filtered and the cake is discharged either by a scraper, or with corrugated rolls, or by water jets.

Soon after Al Genter invented the American filter he developed, practically simultaneously with J. F. Borden, but working entirely independently of him, a filter-type thickener, which employs tubular filter elements submerged in a tank. These thickeners, known in one case as the Genter thickener, and in another case as the Oliver-Borden thickener, are extensively used in the carbonation process of beet sugar manufacture, and to a limited extent in metallurgical plants. The major differences between the two are that the valve mechanism is totally different and the Oliver-Borden uses wire wound tubes. Nearly ten years prior to the development of the filter-type thickeners employing tubular elements, the writer had developed a filtering thickener utilizing leaves of the Moore type, in which the leaves were individually connected to a mechanically driven, multiple-ported valve, similar to that used on the Oliver filter.

In this review no attempt has been made to cover the whole scope of filtration, or to even mention all kinds of filtration or types of filters which are at present being marketed. A review of the several hundred different types of filters which are disclosed in the patent art, not including thousands of patented modifications of basic types, is beyond the scope of this article, and no attempt whatsoever has been made to include well known types of sand filters used for water filtration.

CRYSTALLIZATION

By H. B. CALDWELL
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CRYSTALLIZATION is an extremely old unit operation although it is one that has been developed beyond the most primitive methods only within the last few years. Its record far antedates the Christian era, an old Chinese print, for example, of 2700 B.C., showing the use of artificial evaporation and crystallization in the production of salt. Almost no improvement in methods occurred until modern times. At some unrecorded date the device of introducing twigs or strings into the mother liquor, to collect the crystals and hold them off the bottom, was introduced, as has been shown by Agricola (1556). In any event, these early crystallizing methods made use of shallow open tanks, air cooling of the surface, and batch operation.

It is probably only within the last 50 years that any effort has been made toward improvement. One of the early advances was to speed the cooling by blowing air over the surface of the liquor. At about the same time various expedients to control the rate of cooling through the sides of the tank were introduced, including lagging of the tank in order to reduce the temperature loss, for some products, and sloping of the tank sides to increase the cooling rate, for other products. Which method was used very often depended on the personal preferences of the designer. Another method employed to increase the cooling rate was to place the tank on piers so as to secure good air circulation on all sides.

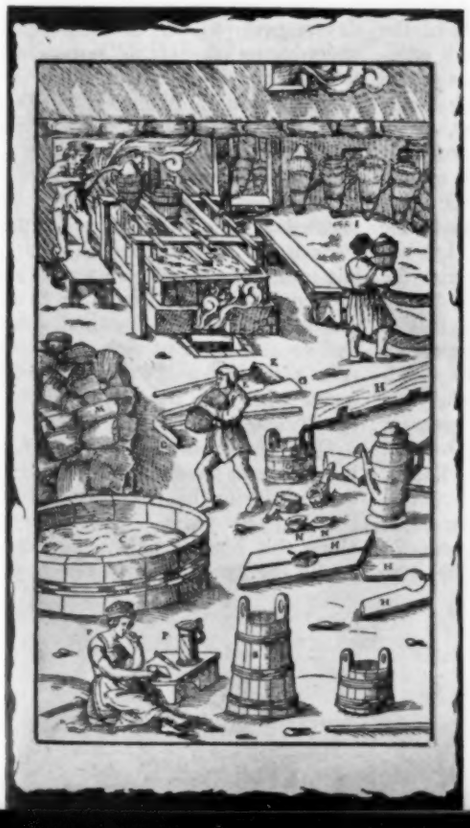
Even these improved methods suffered from much the same disadvantages as the primitive equipment. All of them required excessive floor space, produced non-uniform crystals, required excessive hand labor, occluded impurities, and made production dependent upon weather conditions. The next phase of development, which came with the introduction of air-cooled, continuous crystallization, eliminated many of these disadvantages. The first of the new devices, the Wulff-Bock rocking crystallizer was used extensively in Europe, but only to a very minor degree in the United States. This crystallizer consisted of a trough set on rockers and cooled by natural convection. In a somewhat later development, the crystallizer was hooded and air blown over the liquor surface by a fan. About the same time the agitated iron-tank crystallizer, with water cooling coils, was introduced for batch operation. Quite recently a continuous crystallizer, the Mitchell, was brought out in England, consisting of a rotating tube similar to a rotary dryer through which cooling air is blown.

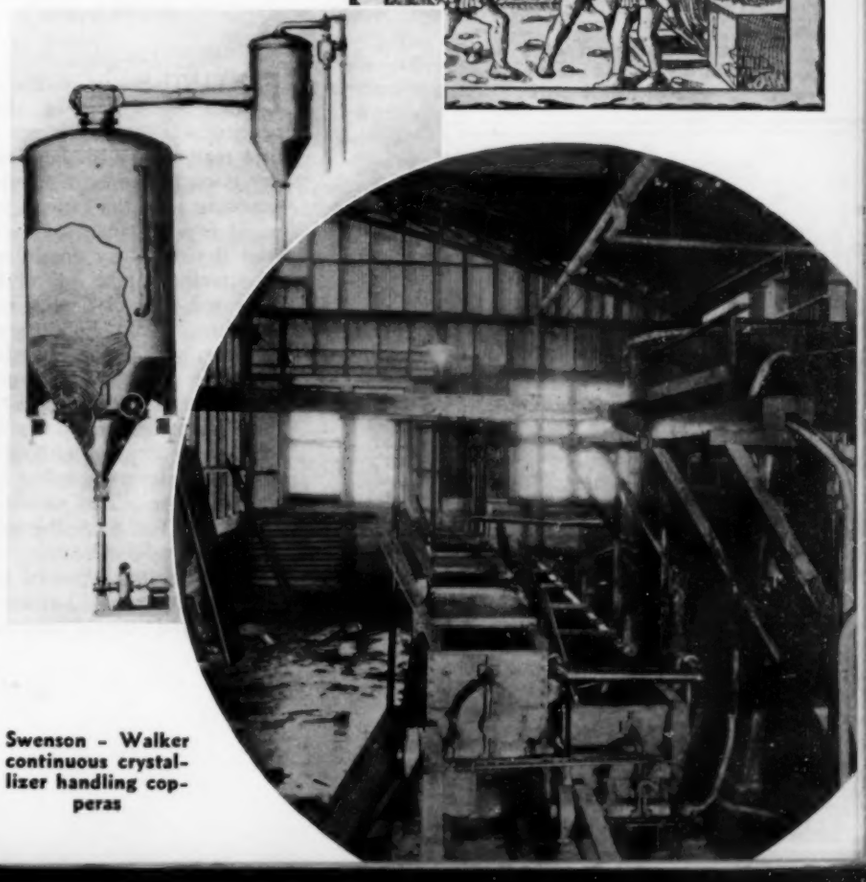
The next stage of development, that of the water-cooled continuous crystallizer, took place shortly prior to 1920, the first commercial application of this type, the Swenson-Walker crystallizer, having been made in that year. This crystallizer is the only one of the type which has received widespread adoption and in the United States has been replacing many installations of earlier types. It was the first crystallizer in which the cooling surface could be kept clean and thus made possible high capacity, subject to theoretical design. It was the first giving truly continuous operation. It was capable of greater crystal size uniformity, but until recently, it has been subject to rather poor con-

Left: Early salt factory, according to Agricola, with master boiler packing crystals in baskets

Right: Evaporating and crystallizing "vitriol" (probably copperas) in Agricola's time

Below: Vacuum crystallizer, most recent improvement in this unit operation





Swenson - Walker continuous crystallizer handling copperas

trol of crystal growth owing to a lack of operating technique.

At about this same time, a double-pipe type crystallizer was introduced but made little impression on industry because of the need of frequent wash-outs, lack of control of crystal size, the production of an excessive amount of fines, and the existence of a high pressure drop. Another crystallizer of this period was a rotary drum type, similar to a flaker, with cooling water on the inside and a scraper outside. The crystals were found to be extremely fine in size, badly agglomerated, and with irregular faces.

Another crystallizer of this period, developed in 1925 by Henry Howard, resembled in appearance some of the hydraulic classifiers employed in metallurgical operations. The resemblance is more than superficial in that an attempt to control crystal growth through the classifying action was the reason for the design adopted. This design employed a vertical, water-jacketed conical body with upward flow of the liquor. This crystallizer has never been employed to any extent.

Recent Developments

Although we have described several phases in the development of crystallizer, it is significant that the aims of crystallization processes seem to have divided themselves into but two phases, one prior to 1925 and the other, since that date. Before 1925 the emphasis in design was placed on heat removal, low labor cost, continuous operation and fairly uniform crystal size. However, little attention was paid to the absolute control of crystal size and uniformity. Since that date the advantages of crystal uniformity have come to the fore. With increasing competition, specifications have become more and more severe. Attractive appearance of packaged products has become important and free-flowing properties required. Some requirements of crystal shape and size, in fact, have reached the stage of unreasonableness. The meeting of these requirements has been aided by the work of Miers in the years prior to 1927. His super-solubility curve and concept of the metastable region (*J. Inst. Metals*, **37**, 1927, pp. 331-350) ushered in the most recent period in crystallizer development. Further light has been shed on the theory by Ting and McCabe (*Ind. Eng. Chem.*, **26**, 1934, p. 1201). For these developments the vacuum crystallizer makes possible ideal operation.

Vacuum crystallization was first developed in Europe in connection with the recovery of potash salts. It was later employed for the same purpose in the United States but, prior to 1932, did not employ vapor compression in attaining temperatures lower than those possible with the available cooling water. In these early designs, the crystallizer body was connected to a water jet or surface condenser and vacuum pump. The first United States patent on vacuum crystallization (which, strangely enough, made no mention of crystallization but only of vacuum cooling) appeared in 1917 and was of this type. The author's patent of 1932 described the first vacuum crystallizer to employ steam jet compression of the vapors. This method greatly lowers cost, makes possible easy handling of acid conditions and permits either batch or continuous operation. It is possible to say today that the vacuum crystallizer excels all former types except for use with solutions of very high excess boiling point or where the final temperatures are much less than 32 deg. F. It should be noted, of course, that by the use of steam jet compression, very much lower temperatures are attainable than are those where the degree of vacuum is limited by the temperature of the cooling water.

Substantially coincident with the development of the form of vacuum crystallizer described, was the Oslo type, developed by Finn Jeremiassen. This crystallizer (*Chem. & Met.*, **39**, 1932, p. 594-6) has appeared in various forms, including vacuum and non-vacuum types. Its interesting results are attained through the use of a perforated bottom through which an upward flow of liquor is maintained, holding crystals in suspension and permitting their growth. Full use of Miers' concepts are applicable in this form of apparatus as in other recent vacuum crystallizers.

DRYING

By THOMAS K. SHERWOOD

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Agricola's equivalent of a muffle furnace: drying and roasting ore in earthenware pots

DRYING is one of the oldest of the unit operations of chemical engineering. History does not tell us of the first man to dry his bear-skin by hanging it on a tree on a windy day, or by exposing it to the radiant heat from his wood fire. Most of our modern industrial drying is by conditioned air, and we attempt to take full advantage of the increased rate of drying with high air velocities. We no longer trust the weather, but our basic method of drying has not changed appreciably. The ancient man well realized the benefit of the radiant heat from his fire in speeding up the drying, although today few industrial dryers employ heat transfer by radiation. The reason is that we have not found a thermally efficient source of radiant heat.

The principal types of modern dryer for solids include (1) rotary dryers, (2) cabinet and tunnel dryers, (3) pan dryers, and (4) can or drum dryers for sheet materials. It is not difficult to trace each of these back 60 years, and find descriptions of dryers which differ but little from their modern prototypes. Although improvements along basic lines have been relatively few, gradual improvement along various lines has increased dryer efficiencies and capacities. Forced air circulation within the dryer has replaced natural convection, and improved mechanical features have increased dryer capacity and decreased fuel or steam consumption. It remains true that drying by mechanical pressure, where it may be employed, is usually cheaper than air drying.

Our understanding of the engineering problems involved in the unit operation of drying has improved greatly in the last 30 years. The development along this line started in the same year as did the American Institute of Chemi-

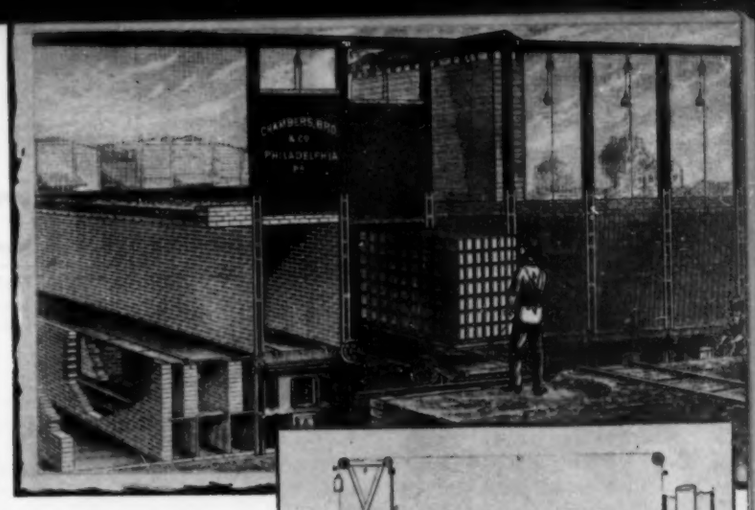
cal Engineers, with the publication of the Grosvenor humidity chart in the first volume of the Institute's transactions. This chart was improved and brought to the attention of the mechanical engineers by Willis H. Carrier, in 1911. It made possible a great simplification of all air-handling calculations in the fields of humidification, dehumidification and drying. So valuable did the humidity charts become that the technical press began publishing humidity charts of all sizes, shapes and types; logarithmic coordinates appeared, linear coordinates, alignment charts, tables of values, and even a slide rule for humidity calculations.

With the development of the humidity chart has come a better understanding of the wet-bulb psychrometer. Although over a century old, this instrument is still the most widely-used means of determining the moisture content of air. The wet wick assumes an equilibrium temperature such that the heat input from the warmer air just balances the heat output by vaporization and subsequent diffusion of water vapor back into the air. Mr. Carrier noticed that in a number of Weather Bureau tests, the measured wet-bulb temperatures checked very closely with the calculated temperatures of adiabatic saturation. The temperature of adiabatic saturation is the equilibrium temperature reached by a definite quantity of air cooling adiabatically in contact with water. It became common practice to assume the identity of the wet-bulb temperature and the temperature of adiabatic saturation, and to use the adiabatic cooling lines of the standard humidity charts in the interpretation of psychrometric data.

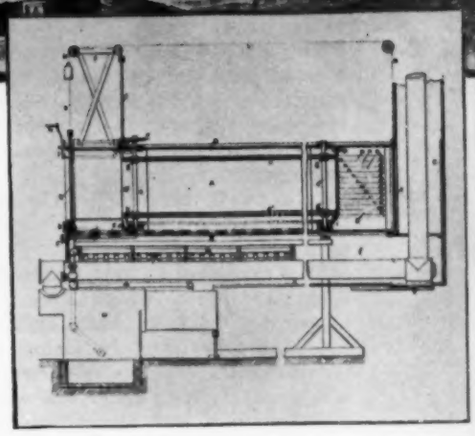
Measurements of wet-bulb temperatures for various organic liquids, however, made it clear that the wet-bulb temperature and the temperature of adiabatic saturation are not necessarily the same. By a strange coincidence of nature, the diffusion coefficient of water vapor in air is such that for water and air the two temperatures are very nearly the same. The use of the adiabatic cooling lines for the interpretation of psychrometric data has no theoretical justification, although for water and air it gives very nearly the correct result.

During the last 15 years the mechanism of drying, and the factors which influence the rate of drying, have been the subject of intensive study. As a result, we now have a clearer understanding of the way in which water moves through the solid and diffuses from the solid into the air. The drying characteristics of many different types of solid have been studied, and it is possible to predict approximate drying times for various solids under various conditions.

About ten years ago Tuttle and the writer, in this country, and Lederer in Germany, applied the Fourier integrals of the heat conduction equations to the diffusion of moisture in a slow-drying solid. Newman and others have greatly extended these applications. In spite of our lack of knowledge of the exact method of moisture movement in many cases, the equations derived have been successfully applied to the drying of many slow-drying materials. Data on the critical moisture contents for many common materials have been collected, in order that the Lewis exponential relation may be used to approximate drying times in engineering calculations. The factors affecting the rate of drying in the constant rate period are now fairly well understood, and it is possible to predict the rate of drying in this period with fair precision.



Old Chambers brick dryer, claimed to dry 25,000 brick per ton of coal (Appleton's Cyclopaedia of Applied Mechanics, 1892)



Conveyor dryer with material carried on trays and heat supplied by steam pipes (Eng. Pat. 6,873, 1889)

Future Work

In the experimental field the next few years will probably see an exposition of the true rôle of capillarity in the movement of moisture through granular materials. This problem is of interest not only because of its importance in drying, but because of its relation to problems of the petroleum engineer, the agricultural physicist, and the wood technologist. Research on drying clays will perhaps lead to a better understanding of the relation between drying and shrinkage, and a method of predicting the safe drying rate of any special shape in a given clay. That interest in the mechanism of drying is increasing is evidenced by the large number of publications in this country and from abroad. In England, Dr. Mellor of the British Refractories Research Association, and the workers at the Forest Products Laboratory, have made valuable contributions. Some of the best work on clay has been done in Canada by the Ontario Research Foundation. The Japanese, at Kyoto, have published several interesting articles recently, and in Russia the government is carrying out a broad program of research on drying at the Drying Research Laboratory of the Heat Engineering Institute, in Moscow.

In the United States, work on various phases of drying is under way at a number of government, industrial and university laboratories. The Forest Products Laboratory, at Madison, has done some excellent work on moisture movement in wood. At the Massachusetts Institute of Technology, the study of drying started by Dr. W. K. Lewis, about 1916, and carried on by the writer in 1926, is being continued with the object of studying the mechanism of drying and the drying characteristics of various industrial materials.

The work to date on the mechanism of drying has placed drying problems on a quantitative basis. The quantitative effects of air velocity, air humidity, temperature, and dimensions of the solid on the rate of drying are fairly well known for a number of types of material. It has been found that high air velocity may speed up drying while the material is fairly wet, but that air velocity may have no effect on the rate of drying in the later stages. Various modifications of the methods of drying of sensitive materials, such as leather, clays and other substances which crack or discolor, have made possible shorter drying times and increased efficiencies. Many important applications of the study of the mechanism of drying may be expected in the future.

EVAPORATION

By W. L. BADGER
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FOR MANY thousands of years there was only one method of hastening natural evaporation, namely, to put a clay or metal pot in hot coals or support it over a fire. This existed, with very minor modifications, practically to the beginning of the 19th century. The apparatus was never standardized except for particular purposes.

One exception to this statement can be made. In the manufacture of salt, the earliest method was to build a hot fire, with or without the inclusion of a number of large stones. When the fire was at its hottest, either sea water or water from a salt spring was poured over the mass and the ashes were scraped up and used as salt. This, of course, was later refined so that the boulders were scraped clean of fire and ashes before the water was poured over them, but the principle was the same.

Through the northern part of Europe, from prehistoric times on, the Celts seem to have been the professional salt-makers. Most of the important salt-making centers of Germany are known to have originated in Celtic times and to have been operated by the Celts long before the Teutonic invasions. Even after the Teutonic invasions, the principal groups of salt-makers formed little islands of Celtic survival among their Teutonic neighbors; and as late as 1875 it was remarked that the salt-makers of Halle were of a different stock than the Germans and were probably decidedly Celtic. In this connection it is interesting to note that the good Irish name of Halloran is an ancient Celtic word and means "salt-boiler."

In the districts where Celtic salt works are known to have existed, extensive ruins are found which, until relatively recently, have not been understood. Apparently four or six upright posts of stoneware carried a flat stoneware slab several feet each way. On top of this were more posts and another slab and so on until the structure was several layers high. The flat slabs were provided with holes at alternate ends. A fire was built under this stack and kept up until the whole mass of stoneware was highly heated. Salt brine was then poured on the top slab and allowed to run down through the whole assembly. In this manner evaporation was carried out without contaminating the salt with the ashes from the fire.

Some time in the very earliest of the Middle Ages the form of pan for the direct boiling of salt became standardized and thanks to the salt-boilers' guilds, was never allowed to vary in size or construction. So, for instance, the salt pans shown by Agricola in 1556 were still used without change as late as 1750.

The construction of such a pan is shown in Fig. 2. The pan was about 6 ft. by 9 ft. and about 9 or 10 in. deep. It was made of relatively small pieces of iron because in those times the only iron available was hand-puddled wrought iron, and that, of course, could only be made in relatively small batches. The pan was so weak that it would not support its own weight of brine. Consequently, at the corners of the pan wood stakes were driven into the ground, and on these stakes there was erected a framework of boards or iron bars. From these, hooks were hung that supported the pan through the staples shown on the bottom. The pan was fired by wood or straw and there was no stack, so that the flue gases merely escaped into the room. (See also page 213.)

In the late 1700's, the pans had grown considerably larger, as is shown in Brownrigg's Treatise on Salt Manufacture, and elsewhere, but the method of building them was still the same. Fig. 4 shows the construction of a salt pan as it appeared in an old French encyclopedia of 1771. Cane juices were also boiled for the manufacture of sugar in practically the same apparatus.

First Vacuum Pan

I have not been able to determine when steam was first used in coils and jackets, but this must have been prior to 1800, because in 1812 Howard built the first vacuum pan in a Liverpool sugar refinery. His pan is shown in Fig. 5. It is a single-effect pan and used a typical jet condenser not greatly different from those now in use.

Howard's pan was not much used on the Continent, but Roth, using a part of Howard's idea, built a pan that was very popular. He simply connected the pan to a sizable reservoir through which there flowed very large quantities of cooling water. When the reservoir was so filled with air or non-condensed gases that the vacuum was too poor for satisfactory operation, it was disconnected from the pan, pumped out and the operation repeated.

The actual origin of the principle of multiple-effect evaporation is a subject over which there has been considerable controversy. There is no question, however, but that the first multiple-effect evaporator to be actually built and commercially operated was built by Norbert Rillieux in Louisiana in 1843, Fig. 6. This is covered by U. S. Patent No. 3,237 of August 26, 1843. The bodies of his evaporator were horizontal tube bodies and the vapor connections were

Fig. 1—Using heat of a hot spring for evaporating salt (Agricola)

Fig. 2, Lower Left—Details of salt pan described by Agricola

Fig. 3—Evaporating saltpeter solution (From "Aula Subterranea")

all made through the cast-iron supporting columns. A peculiar feature, not only of Rillieux's evaporator but of all early sugar evaporators, was that vapor from the first effect was divided. In a four-body apparatus, for instance, the first three bodies formed a triple effect, operated in the usual manner. The fourth body was the finishing pan and was also heated by vapor from the first effect. Thus the number of effects was always one less than the number of bodies. It took a number of years for designers to realize that this particular method of operation was not inherently connected with multiple-effect evaporation.

The vertical-tube type of evaporator was first built about 1850, apparently from Rillieux's drawings. Robert, director of the sugar factory at Seelowitz, Austria, is usually credited with inventing the vertical-tube evaporator, but apparently he did not invent the construction. What he did was to build the first simple multiple-effect evaporator, departing from Rillieux's idea of making one body a finishing pan. In his construction the number of effects was the same as the number of bodies.

The vertical-tube, or Robert, evaporator immediately became the standard construction, although it went through a number of modifications. The first vertical-tube evaporators were built without down-takes. The central downtake appeared, however, within a very few years after the first vertical-tube evaporators were built.

The next important step was the development of the horizontal type evaporator, in 1879, by Hugo Jelenik and F. Wellner. This had instant success and became very popular, but later its popularity declined in Europe, although it maintained its hold in the United States until very recently. At about the same time (1877) Riedel built the first basket-type, vertical-tube evaporator, a design that is still in use.

The Kestner evaporator was first patented in 1899. It was a tremendous success from the very beginning, but not entirely because of its engineering merits alone. The Kestner evaporator appeared very shortly after the Brussels convention, in which the beet-producing countries of Europe agreed to discontinue bounties on beet sugar and to impose a tariff on all sugar imports on which a bounty had been paid in the country of origin. This forced European beet-sugar manufacturers to look for means of decreasing costs, and the first direction in which they turned was to put more effects on to the evaporators. Since the evaporators were already installed, and since the power units (which in those days were reciprocating non-condensing engines) could not be operated at higher back pressures, it seemed as though this tendency toward more effects would have to stop with the triple. The Kestner proved able to evaporate juices at high temperatures without discoloration and this made possible the introduction of the preevaporator heated with steam at higher pressure than the engine exhaust. The sugar industry took up the preevaporator idea so enthusiastically that throughout Europe an enormous number of Kestner bodies were installed for this purpose. For some reason or other, the Kestner was never enthusiastically received in the United States.

In comparison with the long history of steam-heated evaporators in the sugar industry, it is interesting to note that the first multiple-effect evaporator for salt manufacture was built in 1888. In general, other industries lagged far behind the sugar industry in adopting the latest evaporation methods until within the last 15 or 20 years. In the past few years, however, it would almost seem that the reverse had become true.

The literature of the sugar industry in the last 75 years has shown a most bewildering variety of evaporator constructions, most of which never existed except on paper and practically all of which are now forgotten. No really new or radical ideas in this field have occurred for a long time, with the possible exception of the forced-circulation evaporator. Even thermocompression, considered to be a very recent innovation, was clearly described in an article written in 1840. The reason that evaporator devices do not show such great antiquity as pumps, and other strictly mechanical types, is that evaporators use steam, and steam was not generally available until after the time of James Watt.

[*Editor's Note*—Alfred L. Webre, evaporator engineer of the United States Pipe & Foundry Co., tells an interesting story of Norbert Rillieux's experience with one of his early multiple-effect evaporators, which shows that the way of the innovator, like the transgressor, is hard. It seems that Mr. Rillieux sold an installation of multiple effects to Valcour Emme, the owner of a sugar factory in Louisiana. As he had made performance guarantees of capacity, Mr. Rillieux attempted to carry out a 24-hr. run, but for some reason could never accumulate sufficient cane. Finally, by some subterfuge, he managed to do so and commenced the acceptance test on a cold December day. As evening wore on, the vats were finally filled with hot sugar and Mr. Emme requested that the test be postponed, which Mr. Rillieux refused to do. When, shortly, the sugar overflowed, the owner became very angry, called Mr. Rillieux aside and demanded to know the amount of his bill. Then having handed him a check in full, he unceremoniously ejected the inventor who had no recourse but to pack his belongings and walk 2 miles through the mud and rain to the levee, where he caught the 3 a.m. boat for New Orleans.]

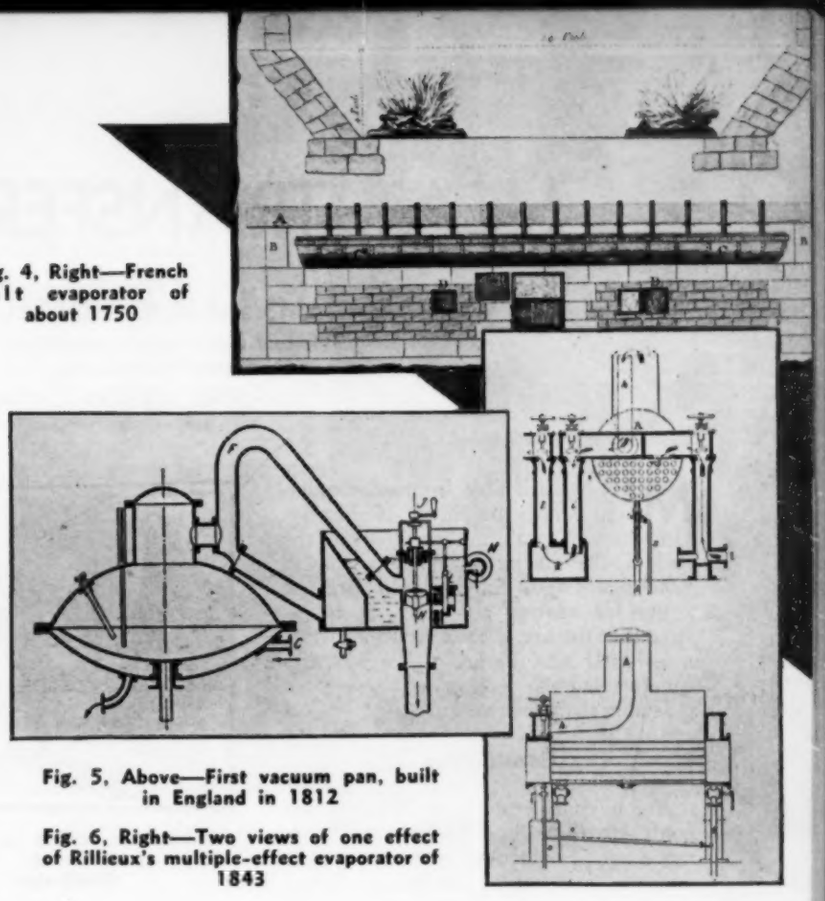


Fig. 4, Right—French salt evaporator of about 1750

Fig. 5, Above—First vacuum pan, built in England in 1812

Fig. 6, Right—Two views of one effect of Rillieux's multiple-effect evaporator of 1843

HEAT TRANSFER

By W. H. McADAMS and H. C. HOTTEL

Respectively Professor and Associate Professor of Chemical Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

MAN has benefited from solar radiation since the dawn of history. However, it was not until near the end of the glacial age, approximately 8,000 years ago, that he learned to use a fire for heating purposes. It is related that the art of cooking began when a fowl fell into the fire and it was discovered that the cooked meat was more palatable than the raw.

Alchemistic devices for blowing a flame (John French, "The Art of Distillation")

Conduction

For a considerable period there was confusion regarding the relative importance of conduction and convection under a given set of conditions. When heat is being transferred from a hot liquid through a metal wall to a cold liquid, it is now recognized that three temperature differences are involved, and that the temperature drop through the metal may be only a fraction of the overall temperature difference. However, at one time it was thought that the entire temperature drop from hot to cold liquid was attributable to the metal itself. Later, Fourier clearly enunciated the law of thermal conduction, thus defining the thermal conductivity. However, the technique of measuring thermal conductivity went through a considerable period of development. With the basic differential equation available, mathematicians derived an involved expression for the heat conduction along a rod or "bar-fin," heated at one end, and subject to a varying surface heat loss, depending on the distance from the hot end. Temperatures were measured by thermometers inserted in holes in the bar, but the thermal conductivities so obtained were only approximate for a number of reasons, one of which was that the theoretical equation involved the heat losses by convection and radiation, which varied with position. Nevertheless, many of the earlier thermal conductivities of metals were obtained by this complicated and somewhat unsatisfactory procedure, which was in use as late as 1893. Later, physicists obtained reliable values from simple, steady-state experiments by measuring the actual heat current density and temperature gradient, eliminating heat losses by use of the "guard ring." Today, standard methods of measuring the thermal conductivity of insulators are available for temperatures up to 1,000 deg. F., and methods are available for refractories above 1,000 deg. F. (See G. B. Wilkes, *Chem. & Met.*, **41,** 1934, pp. 232-4.) For liquids and gases the measurement of thermal conductivity is complicated by convection effects, and for gases, by radiation also. Fairly good technique is now available, especially for liquids, but is not standardized.

Modern thermal insulation and refractories play an important rôle in the performance of high temperature furnaces of many diverse types. For intermittent furnaces, which are frequently heated and cooled, low volumetric heat capacity is advantageous, as well as small thermal conductivity. Only recently has the public become familiar with modern thermal insulation.

Convection

Long ago Newton measured heat losses from containers filled with water, and this experimental study of heat transfer by the combined mechanisms of free convection and radiation was continued by others, notably Peclet.

Since the definition of the convection coefficient of heat transfer is arbitrary, convection problems involve (1) measurements of heat transfer coefficients for various conditions, so that the designer will know the results obtainable under given conditions and what factors are of controlling importance; and (2) the correlation of the coefficients, in order that the effects of changed conditions can be predicted

Left: Furnaces and dust chamber shown by Agricola

Left: Two furnaces from Agricola which have a surprisingly modern appearance

Bottom left: Glass melting furnace used in France about 1700

Above: Forge and bellows shown by Biringuccio (Pyrotechnia)

Left: Variety of furnaces for copper smelting (Aula Subterranea)

with reasonable assurance. Although the desired value is the overall coefficient from the warmer fluid, through the retaining wall, to the cooler fluid, the problem is generally attacked by dividing the overall resistance into its component resistances, which are usually reported in terms of individual coefficients. A better understanding of the nature of the motion of fluids in pipes was contributed by Osborne Reynolds, who made the classical experiments on the flow of clear water through a glass tube, and by injecting a thread or band of colored water, observed the transition from streamline to turbulent motion at the critical value of the dimensionless ratio now called the Reynolds number. Reynolds predicted that linear velocity, V, and fluid density, ρ, would have equal importance in affecting the convection coefficient, h, for turbulent flow in pipes, and called the $V\rho$ product "mass velocity." This prediction was confirmed by Nusselt, who also found that the heat transfer coefficient was an exponential function of the mass velocity over a considerable range, and presented a correlation of data for three gases, expressed in terms of dimensionless ratios.

Although much yet remains to be done (see *Chem. & Met.*, **41,** 1934, pp. 233-4), general formulas are available for a number of important cases of both forced and free convection, the equations being based on the results of many independent investigators. Only a few years ago, Schmidt, Schurig and Sellschopp discovered that when steam condenses in a dropwise fashion, the individual coefficients are four to eight times as large as with film-type condensation. Nagle and Drew (Trans. A.I.Ch.E., **30,** 1933, pp. 217-55) have clarified the situation and found that small traces of certain substances promote dropwise condensation. Using a promoter, Nagle found individual coefficients ranging from 10,000 to 16,000 B.t.u. per hour per square foot per degree F. difference from steam to metal. At ordinary water velocities the actual rate of heat transfer from steam to cooling water in a clean surface condenser, with dropwise condensation, may be roughly double that with film-type condensation.

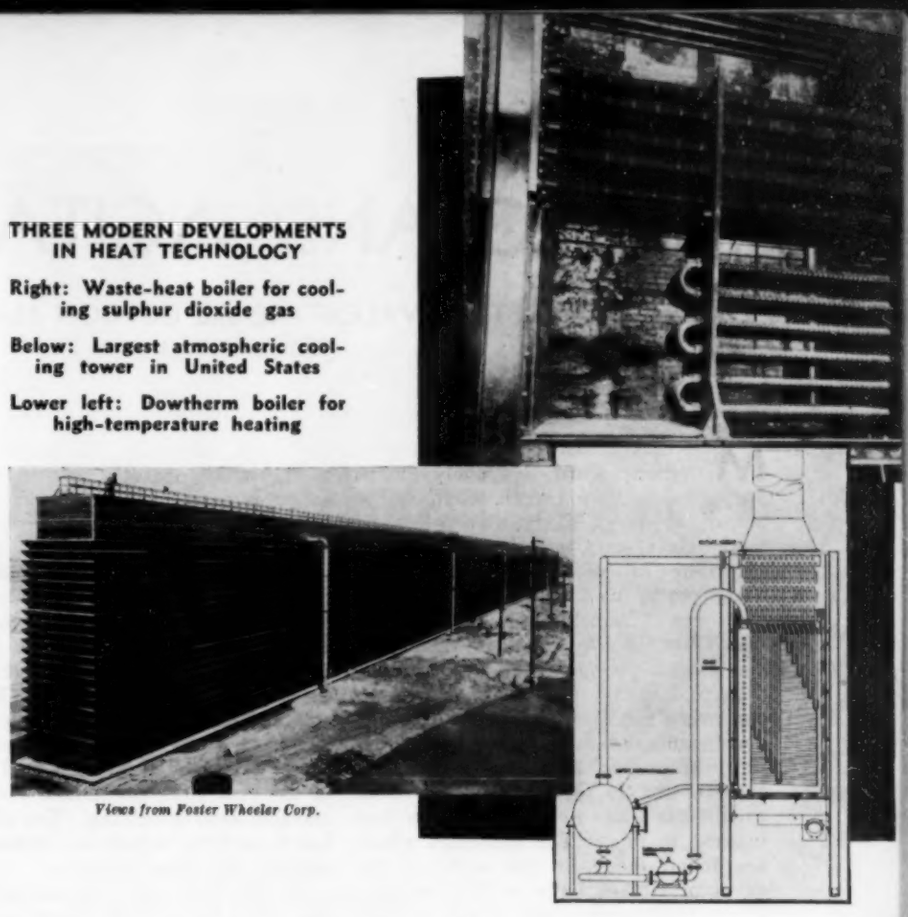
The general public has long been familiar with heat transfer in connection with heating, cooking and the use of ice. However, only recently have they become acquainted with air-condition and automatic refrigeration.

THREE MODERN DEVELOPMENTS IN HEAT TECHNOLOGY

Right: Waste-heat boiler for cooling sulphur dioxide gas

Below: Largest atmospheric cooling tower in United States

Lower left: Dowtherm boiler for high-temperature heating



Views from Foster Wheeler Corp.

Radiation

The origins of modern concepts necessary to a quantitative evaluation of heat transmission by radiation lie in the early work of physicists who were on the whole not interested in the application of their findings to the subject at hand. As early as the latter part of the 18th century, Prevost propounded his theory of exchanges, pointing out the necessity for the concept that all bodies are radiating at all times, that a system in thermal equilibrium is characterized by equality of emission and absorption on the part of every element in the system.

What was perhaps to be the biggest single step towards clarification of problems in radiant heat transmission was taken by Kirchoff, in 1859, when he introduced the concept of the perfect radiator or black body and proved that the ratio of the emissive power to absorptivity was the same for all bodies and equal to the emissive power of a perfect radiator.

Tyndall, in the middle of the last century, touched experimentally on almost every phase of modern problems in radiant heat transmission, including in his studies measurements of radiation from, and absorption by, flames, their products of combustion, various organic vapors, and even human breath with and without diets of onions and ale. His writings indicate an amazingly clear conception of the nature of the phenomena being investigated, when we consider that almost none of the sign-posts that guide the present investigator had yet been painted. Some 20 years later Stefan, correlating some of the data of Tyndall and of Dulong and Petit, discovered the proportionality of radiation to the fourth power of the absolute temperature; this important discovery was put on a sound thermodynamic foundation a few years later by Boltzmann.

The first precise studies of the infrared spectrum were made by Langley, who was followed by a host of workers in that field. The basic law of the distribution of energy in the spectrum of a perfect radiator or black body, the study of which gave birth to the quantum theory which so permeates modern physics, was discovered in 1900 by Planck.

In the meantime, other work had been done by Julius and Paschen, which although emphasizing Tyndall's early discovery of the importance of radiation from non-luminous flames, was to lie unused in the libraries for 20 years before being finally converted into material useful to the engineer interested in heat transmission.

Modern developments in radiant heat transmission, as in nearly all fields of engineering, have resulted in part from the use of tools, furnished by the scientist not primarily interested in engineering problems; in part from the quantitative study and semi-empirical correlation of the overall effects of phenomena inherently so complex as to defy investigation of the details of the process.

In acknowledgment we wish to thank Prof. G. B. Wilkes, of M.I.T., for suggestions concerning the section on Conduction.

MIXING AND AGITATION

By KENNETH S. VALENTINE and GORDON MacLEAN
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MORE ANCIENT than the earliest written word, probably more ancient even than speech itself, is the art of mixing. Early man when he mixed clays, sand, and mud to block up the chinks in the stones which kept the drafts out of his cave, never anticipated that he was launching a unit operation which was to go through four more or less definite periods. Nor did he anticipate that every method he developed, and every method brought forth by his descendants, would continue to be used until the present day. It is true, nevertheless, that in this first period, from prehistoric times to 500 B.C., man first learned to mix. The paintings which are found today on the walls of the caves of France have endured because of the paint-mixing skill of the ancients who, even in that day, felt the urge for self-expression.

With the advent of fire as a tool for man's use, and with the cultivation of grain, the race started to mix in earnest. Crude types of doughs were prepared—just as they are prepared today—the fist became a mixer and indigestion was added to men's woes. As baking expanded, the fist could no longer handle the job, so treading was introduced. In many parts of the world today doughs are prepared by this ancient method. Macaroni, especially, needs such treatment, perhaps to give it the proper flavor, and it is actually made by this method in many small plants in Italy today.

The next step in human development brought in pottery, presenting new problems which further advanced the mixing art. When the first clay cooking vessel was made, a great forward step was taken, for no longer could the hand be used as a stirrer. The first stick to stir the first stew to be cooked in the pot was the forerunner of a forest of sticks of all sizes and shapes, in use ever since for almost every conceivable kind of mixing. The alloy still has to be found which can replace wood entirely for these purposes.

As time went on, more and more articles were being made from clay until one day an inventive wife found that hubby could be stunned without serious injury by the sudden application of pottery to a vulnerable spot. This outlet for her emotions was likewise an outlet for pottery stocks and greatly stimulated the budding ceramic industry, forcing it to find easier ways of preparing the clay. Logs and tree limbs were called on to roll out the lumps and beat the clay into condition and such methods held sway for countless centuries. Our illustration shows an early potter engaged in this innocent but energetic pastime.

While all this was going on, another industry had started up which proved to be a great success—the fermentation industry. The amount of stirring given these early attempts was probably out of all proportion to the requirements and undoubtedly the sampling was as frequent as one may suspect it to be today. Within the past two months, excavations at Tepe Gawra, in Mesopotamia, unearthed a seal showing two men stirring the contents of a vat with long poles. This is interpreted to be a scene in a brewery of some 5,000 years ago.

Meanwhile, the human race had acquired beasts of burden. Mixing had been practiced for thousands of years at this time, and the necessity for greater production arose, logically calling for the next great step in mixing art. This was the substitution of animal- for man-power. The change required the development of the first mixing machines using rotary motion. These, although crude, introduced the rotary sweep or paddle, and later, mullers with large heavy wooden wheels to do the mixing. Adaptations of these are today's best solutions to many mixing problems.

Not only in these mullers, but in the great majority of the mixing methods in use today, one thing stands out—that practically every method which has ever been used for mixing is actually employed in some part of the globe today as the accepted method.

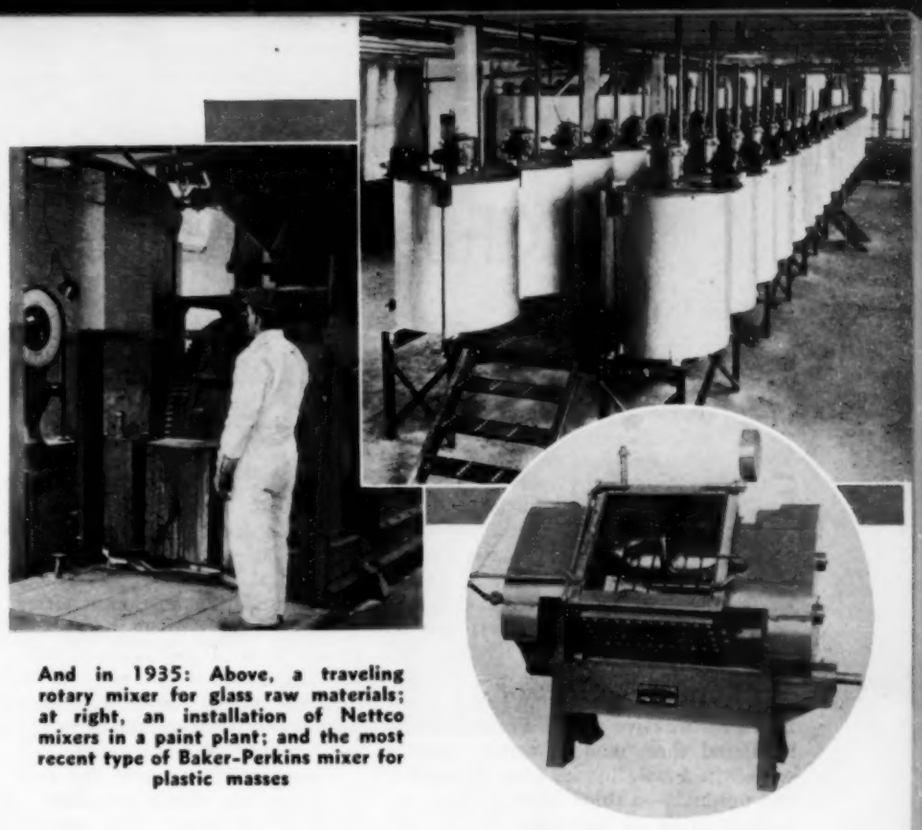
The next mixing era, that from 500 B.C. to about 1600 A.D. was not notable for any significant advances in the mixing technology of doughs, clays, brews, and stews. However, during this period processes for the extraction and refining of metals were originated. Concurrently, the manufacture of very crude chemicals laid the foundation, although a weak one, of our modern chemical industry. Considerable quantities of ore or dirt had to be leached or washed, and crude chemicals such as "vitriol" had to be made and dissolved. Agricola, as our illustration shows, was well acquainted with the early type of paddle mixer developed for this work. It is surprisingly like many mixers now in use—which is not to our credit. The gear drive shown, with its disassembled parts, is worth noting, for it is the precursor of today's gear reducers.

The next period in mixing development, the 290 years after 1600, brought the evolution of the rotary paddle mixer. From the early type employing one or more horizontal blades, it merged into later forms showing a variety of constructions adapted to promote more thor-

De-airing clay was good exercise when Biringuccio wrote his "Pyrotechnia"

Lower Left: Agricola's paddle agitators were strikingly similar to those of today

No alum factor was complete without its stick in Agricola's day



And in 1935: Above, a traveling rotary mixer for glass raw materials; at right, an installation of Nettco mixers in a paint plant; and the most recent type of Baker-Perkins mixer for plastic masses

ough mixing. These changes include, first, the substitution of vertical blades for horizontal; second, the combination of both with diagonals to make the so-called gate mixer; third, the placing of stationary fingers between the blades to promote turbulence; fourth, the bending of the blades to fit more closely the curved walls of containers; and fifth, the so-called "angling" of blades to initiate currents at an angle to the path of the blades. It can easily be seen that this fifth stage is but one step removed from the propeller mixer of today.

Undeniably, all of these last developments progressively improved mixing, but they were only variations of existing designs and not new types. It is also quite certain that none of them came into use until about 100 years ago.

During much of this time, bread was being made by the time-honored hand method, and it was not until 1760 that the first step to mix dough mechanically was announced. In that year the first dough mixer was built by Salignac and demonstrated successfully to the Paris Council, who gave it their enthusiastic endorsement. The device consisted of a sort of harrow, revolving in a pan around a central axis.

In 1789, Ziborghi, evidently to let other nations know that Italy was also in the race for a good 5-cent loaf of bread, developed the first mixing roller, fastened above a flat table. This was, to all intents and purposes, a mechanical rolling pin, but, being anchored, it was no longer suitable as a weapon of connubial offense for the baker's wife. Thus, humbly, was born a type of mixer depending on rollers, which today handles the heaviest mixes with which modern industry has to cope. Rubber compounding and other operations with extremely heavy, rubbery doughs, and plastics in operations requiring thorough blending, dispersion, or comminution, are samples of present uses of rolls. Now, however, two or more rolls are used, usually of heavy construction and often corrugated. If smooth rolls are used they are usually run at different surface speeds.

Although developed for bread-making, the machines of Salignac and Ziborghi had but short life for that purpose. They were displaced by the helical mixer rotating on a horizontal shaft in a container closely surrounding it, an invention of Lasgorseix, in France, in 1829. Now the way was paved, not only for the development of the modern dough mixer, but also for mixers to be used for many other purposes. This is the first instance where the principle of the screw had been applied to the operation of mixing.

From this time, until 1853, there was a gradual modification of the interrupted screw type, with low pitch and solid flights, to an extremely high pitch (several times the diameter) and flights which were, in effect, transformed into curved, horizontal paddles. This blend of screw and paddle principles is incorporated in the dough mixer which the Frenchman, Boland, patented in 1853. Definitely it was the prototype of the modern dough mixer illustrated in this article. The machine of 1935, however, had two shafts and two troughs with only a half wall between them. The screw mixer of Lasgorseix also underwent a metamorphosis along other lines, giving us today the pug mill for clay, the ribbon mixer for dry powders, and the soap crutcher, all of which are now firmly intrenched in industry.

What we may call the modern period, from 1890 until the present, has been positively meager in basic developments in mixing machinery. In general, these years have shown tremendous scientific progress, but there is little evidence that the flame of genius burned with consuming brightness in the breasts of the mixer men; that is, there is little evidence unless one is misled by externals. Improvements in basic types already established as mixers before 1890 have been frequent, but are not fundamental.

A careful analysis shows that the only essentially new developments in the past 45 years are (1) the propeller mixer, and (2) the turbine mixer, for liquid mixing. Additionally, we may mention (3) the colloid mill, and (4) the homogenizer for obtaining fine dispersions and permanent emulsions. There is nothing really new about the propeller or the turbine, for they had been in use for years for other purposes. The novelty came about in the application of these devices to mixing work for which they were splendidly adapted when properly modified. Take, for instance, the turbine mixer, a type of which is shown in an accompanying illustration. Twenty years ago the turbine had never been thought of for paint mixing and yet there is nothing that can equal it today for doing the work in short time with absolute certainty. 1890 marks the date of the patenting of the first turbine mixer in the United States.

Just why the colloid mill and homogenizer had not previously been developed is uncertain, but perhaps it was because there was no need for such machines before the comparatively recent appreciation of the facts about emulsions and the development of a market for emulsified or homogenized products. In 1890 an "Emulsor" was patented in Sweden, marking the beginning of a need for such equipment. In general principle of operation, it resembled the modern colloid mill, although the latter has incorporated many improvements and refinements worked out during the past 45 years. Naturally, developments like the colloid mill and the homogenizer are of great technical value. Take, for instance, the far-reaching effects of the homogenizer which has become indispensable to the dairy industry through its use in homogenizing milk.

So much for history. What of the future? Our conclusion is that very little has yet been done in mixing, compared to the work which lies ahead, and that better mixing (of men, as well as of materials) is still a universal need. The thing to do is to get busier than ever. Fan the flame of genius and let the sparks fly at one mixing problem after another.

MECHANICAL SEPARATION

By ANTHONY ANABLE

The Dorr Co., Inc.
New York, N. Y.

EONS before the dawn of the crudest forms of civilization on this planet mechanical separation processes must have appeared in primitive form. One day perhaps, a Cro-magnon man, a bit more fastidious than his colleagues, tired of drinking from the streams of muddy water, pouring down in torrents from the ice caps of the glacial age. The germ of an idea may have penetrated his massive skull. For, no doubt, he found that muddy water, quietly settled in a hole in the ground, yielded two products—a thick layer of mud and a clear layer of palatable water. He didn't know it, perhaps, but he had unconsciously hit upon the basic concept of thickening and clarification.

Several light-years later, in the 16th century, when Agricola wrote his classic, "De Re Metallica," the world was on the threshold of the Renaissance, but thickening was still in the Dark Ages. If text and woodcuts are to be believed, thickening had become an important unit operation among the copper concentrators at Neusohl and elsewhere in the Carpathian Mountains. Continuous feeding had been solved. Thus continuous overflow had been secured. But sludge discharge was discontinuous, a shovel and hoe operation at frequent intervals.

Settling cones were used for thickening on a semi-continuous non-mechanical basis in the early period of gold cyanidation, in South Africa, Australia, and the United States, just prior to the turn of the 20th century. The discharge port in the apex of the cone plugged up incessantly and certain definite mechanical limitations prevented the building of large cones.

Then, in 1906, came the first Dorr thickener, the direct progenitor of the thickener of today. It appeared not as a laboratory size model, but as a full scale, 35-ft. working unit and operated continuously throughout the life of the remodeled gold cyanide mill of Mogul Mining Co., Pluma, S. D. Like most successful inventions, the essential principle was simple in the extreme — a slowly revolving set of plow blades that moved the settled solids continuously to the central sludge outlet, without interfering with quiescent settling in the zone directly above. Continuous sludge discharge, as well as continuous feed and overflow, were at last realized.

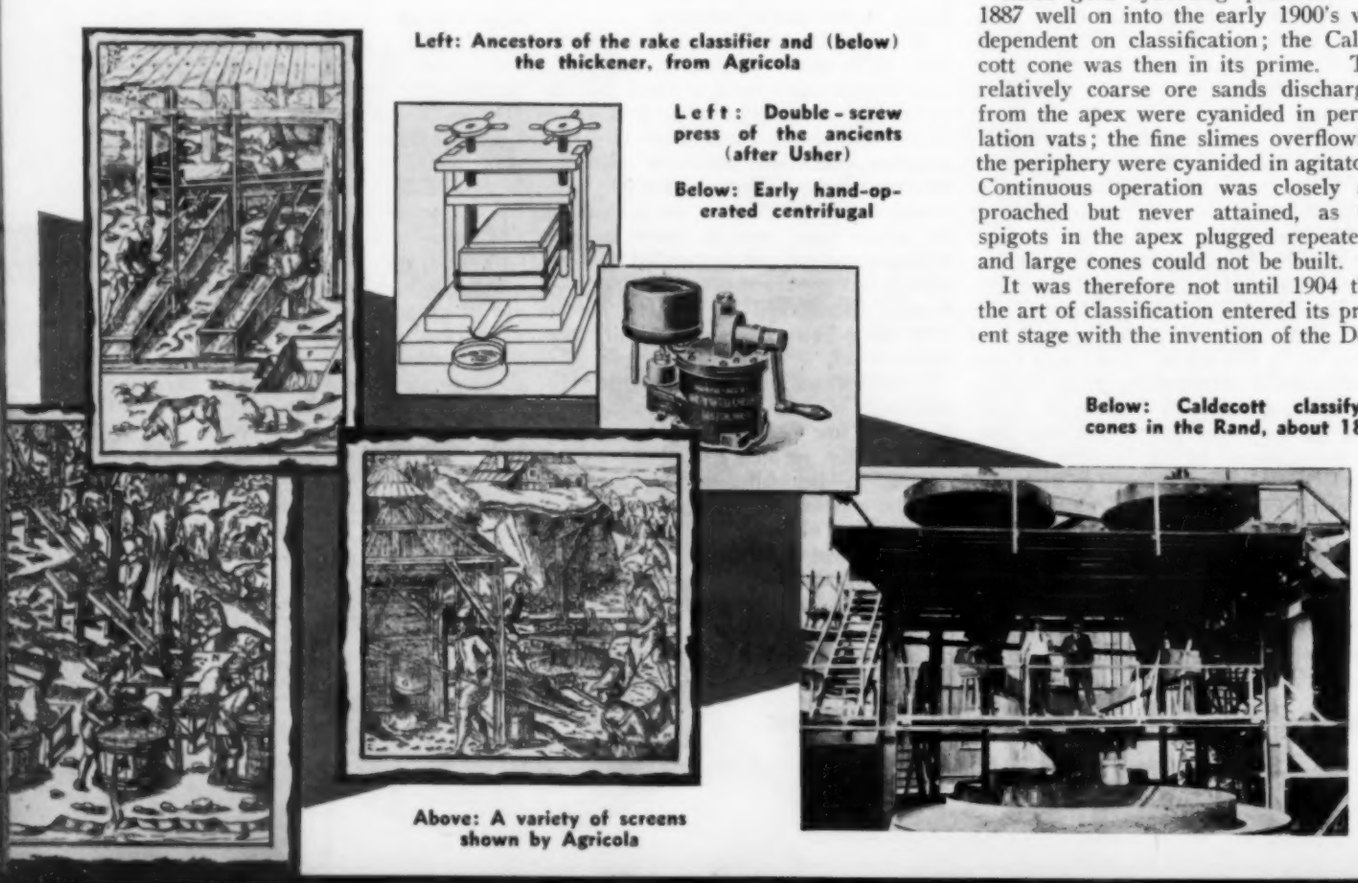
Today's Dorr thickeners are of various sizes and types. The large traction type have been built in diameters up to 325 ft., the tray type has up to seven superimposed settling compartments, each in effect a single thickener, and the washing type has a series of tray compartments operating in series for counter-current washing. This year, the cumbersome unsightly superstructures have been removed to improve appearance, headroom, and accessibility.

Classification was an important unit operation in the middle of the 16th century. Throughout the tin mines of Schackenwald, Erbisdroff, Altenberg, and Geyer, a primitive device, known as a strake was classifying and helping to concentrate crudely crushed tin ore prior to treatment in smelters.

The strake, according to Agricola, was a simple, inclined flume, equipped with a crank-operated paddle, that turned the ore over and over, causing the fine clay, silt, and ore slimes to be buoyed up as a water-born suspension and carried off for separate recovery in a thickening tank. The coarse, washed portion settled to the bottom of the flume and was removed and treated separately. So here in the 16th century were sand-slime separations going full blast, not vastly different from practice on the Rand three centuries later.

Rand gold cyaniding practice from 1887 well on into the early 1900's was dependent on classification; the Caldecott cone was then in its prime. The relatively coarse ore sands discharged from the apex were cyanided in percolation vats; the fine slimes overflowing the periphery were cyanided in agitators. Continuous operation was closely approached but never attained, as the spigots in the apex plugged repeatedly and large cones could not be built.

It was therefore not until 1904 that the art of classification entered its present stage with the invention of the Dorr



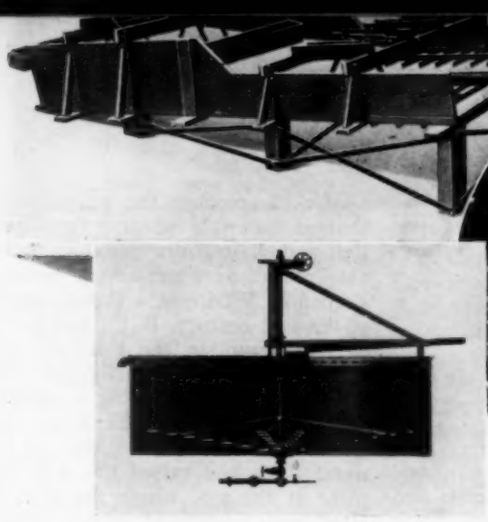
Left: Ancestors of the rake classifier and (below) the thickener, from Agricola

Left: Double-screw press of the ancients (after Usher)

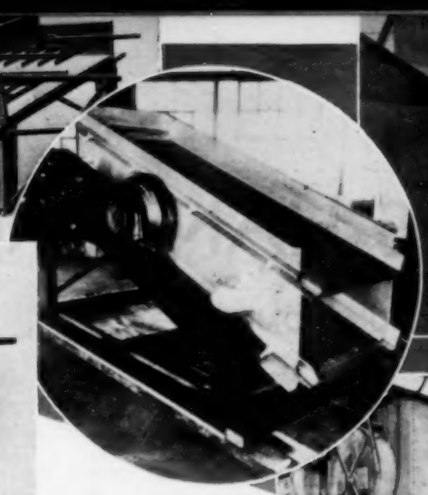
Below: Early hand-operated centrifugal

Above: A variety of screens shown by Agricola

Below: Caldecott classifying cones in the Rand, about 1890



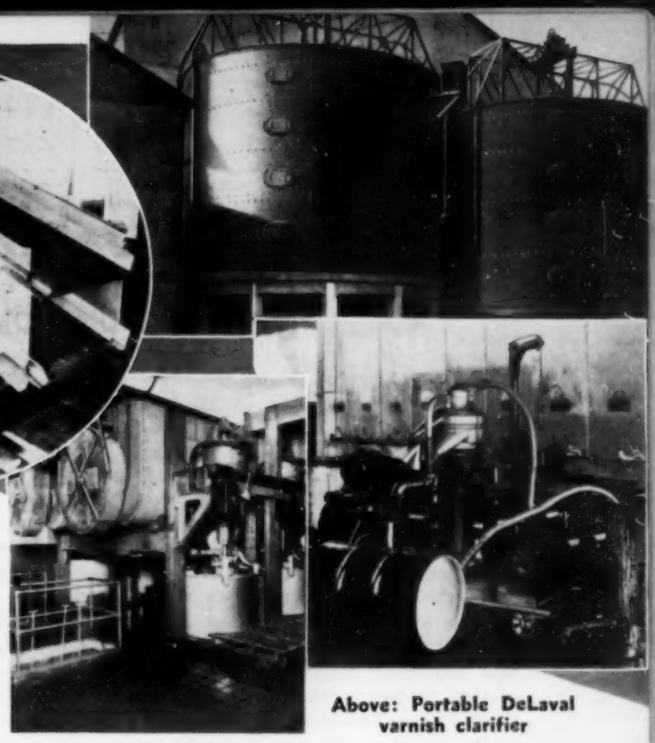
Above: First Dorr classifier and thickener, 1904 and 1906



Above: Modern Tyler vibrating screen

Upper Right: Two modern, four-compartment Dorr thickeners

Right: Group of A.T.&M. Co. centrifugals



Above: Portable DeLaval varnish clarifier

mechanical classifier at the Lundberg, Dorr & Wilson gold mine in South Dakota's Black Hills. Crude cone classification was producing a sand that wouldn't leach and a slime contaminated with sand. Output and extraction were poor and the monthly losses were mounting. To solve this problem the first Dorr classifier was built. The result was a clean, leachable sand, a sand-free slime, and a profitable plant operation that lasted for the life of the mine. The idea and the machine were simple — an inclined trough, a set of reciprocating rakes, an overflow weir for the continuous discharge of water-born fines and a drainage deck for raked sands.

Today the basic principle persists, though the machines differ radically in outward appearance. The big Dorr FX units, 16 ft. wide, are capable of raking 16,000 tons of coarse sands a day. The bowl type for finer separations has been built in sizes up to 28 ft. in diameter. Close separations can be made from as coarse as 10 mesh to as fine as 2 per cent on 325 mesh.

Centrifugal Separation

First use of centrifugal force in developing a separating potential is credited to the Chinese who are said to have used it in purifying tung oil. The history of modern centrifugals is not entirely clear. Indications are, however, that David Weston was actually the inventor of the suspended, basket type, and that he developed it in Hawaii, for use in that island's budding sugar industry some time shortly after 1852, when he opened a repair shop and foundry in Honolulu. Seeing some measure of the large place the centrifugal was ultimately to take, he came to the United States, about 1860, and after making a licensing arrangement for the manufacture of his equipment, which later proved unsatisfactory to him, eventually made a connection with the American Tool & Machine Co., which built its first centrifugal in 1864. It is interesting to note that the suspended centrifugal, which is still the most generally used type of basket centrifuge in the chemical industry, differs today very little from Weston's original design.

Meanwhile, in 1877, Carl Gustaf-Patrik DeLaval invented the liquid-liquid continuous centrifugal separator, which bears his name. Being unsuccessful in commercializing his invention, he returned to Stockholm in 1878, where he built his first successful commercial machine.

Since these early efforts, numerous modifications of the original designs have been brought out, most of which continue in use today. These include small-diameter, high-speed bowls for clarification and liquid-solid separation, semi-continuous basket-type centrifugals, and, finally, continuous basket-type machines in which a rotating scraper continuously removes the solid particles retained on the screen.

Pressing

Pressing, as a means of separating juices and oils from non-rigid substances, was an operation well-known to the ancients in their quest for food materials. Hand and foot pressing, both of which persist today, were doubtless the earliest methods. Later the beam press, in which pressure was applied by means of a weighted lever to a stack of separators, interspersed with layers of material to be pressed, became known to the early Greeks and Egyptians. Considerably before the Christian era, the screw press seems to have been employed in a form not differing greatly from the letter press of Benjamin Franklin's day. And in 1935, so far as batch pressing is concerned, the principles employed are very similar. Only in the case of the expeller type of continuous press, employing a tapered screw, is there a new principle.

Screening

Ancient inscriptions, going back as early as 4000 B.C., show that the art of screening was known even in that distant time. Early practice was described both by the Greeks and Romans of about 150 B.C., when wooden boards or hides, punched full of holes served as coarse screens, while fabrics, animal and even human hair served for finer separations. The beginning of modern practice dates to the 15th century A.D., when the Germans introduced the first screens woven from iron wire. One of Agricola's wood-cuts, reproduced herewith, clearly shows the state of screening in the 16th century, at which stage it remained until the introduction of mechanical screens early in the 20th century.

The rotating trommel screen had been introduced considerably before 1916, when an important change took place with the development of the high-speed, electrically vibrated, inclined screen. This development of the W. S. Tyler Co. vastly improved on the old style tapping screen and introduced a period when many different forms of mechanical screens were brought forth. Ten years later the latter had reached a high state of development and today we have new electrically vibrated forms, and a variety of gyrating screens and mechanically vibrated screen surfaces actuated by rotating eccentric bodies.

MATERIALS HANDLING

By G. L. MONTGOMERY

Mechanical Engineer
McGraw-Hill Publishing Co.
New York, N. Y.

FOUR THOUSAND years or so ago two developments in widely separated regions laid the foundation upon which modern materials-handling has been built. In the valley of the Nile, the early agriculturists found a copious supply of water, but little or no rainfall. Water for herds and crops was tediously dipped up in jars and carried to the point of use, until some early Edison invented a hoisting device quite similar to the familiar well sweep of American colonial days. This device is still in use on the Nile, side-by-side with the most modern water-lifting equipment.

About the same time, on the north China plain, a budding civilization was faced with the necessity of moving more goods from place to place than could conveniently be handled on the backs of men. Draft animals were little help, as their feet sank in the soft loess, making progress slow and difficult. From this dilemma sprang the wheelbarrow, direct ancestor of all carts and cars, down to the latest factory truck or industrial railway.

Built on these foundations, improved devices for effecting the two essential movements of material—vertical and horizontal — slowly developed. The sweep is a simple lever and hence does not contain all elements of modern hoisting apparatus. But in a relatively short time the windlass and the pulley were developed and true hoists and cranes began to appear. Hero of Alexandria, writing in the second century, B. C., described a number of cranes and hoists, some of rather complicated design.

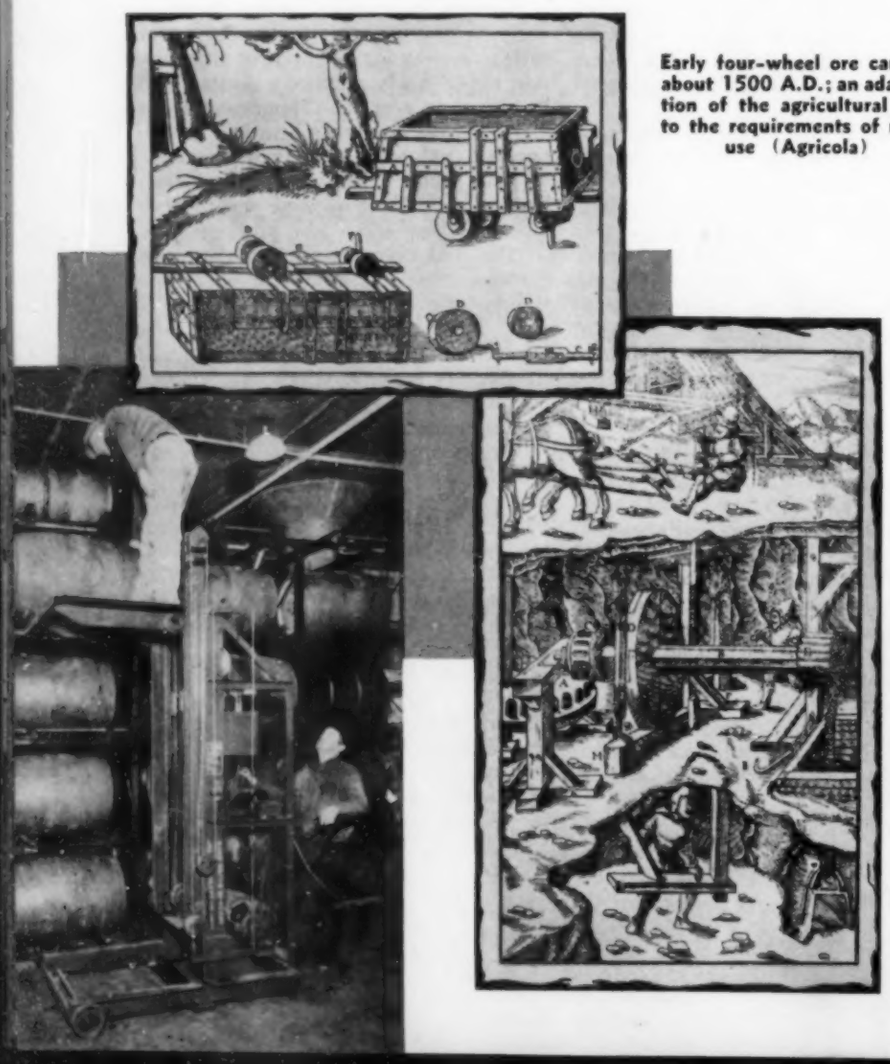
Wheeled conveyance early spread westward from China, so that in Biblical times the Persians, Assyrians, and Egyptians, among others, were familiar with the chariot and cart.

Another development of antiquity was needed to complete the groundwork of modern materials-handling development. Belt and chain conveyors stem from the old "noria" or water-lifting device described by Vitruvius, a Roman architect of the first century, B. C., and by Philo of Byzantium, in the third or second century, B. C. Originally the "noria" was a large wheel, having a number of pots fastened along the rim. As it revolved the pots dipped into the river, were filled, and raised the water to a point at the top, where the pots were tilted and discharged into a chute or pipe. In applying this principle of water moving to wells, the large wheel would not serve, and hence the chain of buckets was developed. In this, the buckets were held on one or more endless belts of rope. At the top of the well, and also at the bottom, the belt passed over small wheels set on axles, the upper axle being revolved by means of a windlass.

One other development was necessary before all the mechanical devices used in modern conveyors, trucks and hoists were available. This was made by Archimedes, of Syracuse, in the third century, B. C., when he designed the screw conveyor as a means of lifting water.

Though all these forerunners of our modern equipment were thus known, and widely used, before the birth of Christ, little or no progress in materials-handling development appeared until the Middle Ages. In the 15th century, two outstanding records were made, among others, which show that mechanical development had been stimulated by the Renaissance in arts and learning that was then nearing completion.

It was at this time that Leonardo da Vinci (1452-1519), the great Italian artist, engineer and scientist, performed those experiments which resulted in the many mechanical designs handed down in his notebooks and which have formed the basis of most mechanical developments since his day. Leonardo designed the first roller chain of which there is record, making possible the later development of chain conveyor so widely used in the modern industrial plant. He also designed the first roller bearing, the belt drive, the link chain belt, and various types of gears and cams. In addition, he applied these mechanisms



Early four-wheel ore cart of about 1500 A.D.; an adaptation of the agricultural cart to the requirements of mine use (Agricola)

Primitive cranes of antiquity developed into the water- and animal-powered mine hoists of Agricola's time

Extreme Left: In 1935 Agricola's two materials handling devices have been combined into a single compact machine, which stacks barrels yet travels on its own wheels

to many machines, thus indicating to future workers how they might be used. He is also credited with introducing the wheelbarrow to Europe in its present form.

Contemporary with Leonardo was the appearance of a book called "De Re Metallica," by the German, Georg Bauer, writing under the name of "Agricola." This book deals with the primitive mining practices then current in European countries and gives, in consequence, an account of the materials handling equipment available, as most of it was then used in mining operations. The interesting reproductions of woodcuts shown herewith are taken from this work and show a wheeled car, the forerunner of present-day industrial railways and industrial trucks; and a mine-hoist from which modern cranes and hoists have been developed.

In the 400 years intervening up to the present, progress in the development of materials-handling equipment has proceeded at an ever-increasing pace. During the first part of this period there was a gradual substitution of mechanical for human or animal power in the operation of trucks, cranes, and hoists. Water-power was first made use of for this purpose, and after that the steam engine and the electric motor, in turn, as they were developed.

During this period many of the modern forms of materials-handling equipment made their appearance. Belt conveyors, now widely used for handling all sorts of materials, seem to have been first used extensively for handling coal toward the close of this period, in the 1890-1900 decade, when building of the large power plants was started. Bucket elevators developed about the same time. Pivoted and V-bucket carriers came along in the next decade, also for coal handling. Development of the gravity roller conveyor belongs to the same period.

Saw-mill operations from 1870 on were responsible for the discovery of the possibilities of the chain conveyor, although it made its appearance here first as a cable conveyor. About that time in Michigan, several mill-supply houses were putting out attachments for cables which made possible the movement of logs, slabs, and boards along wooden runways to various parts of the mill.

Parallel to this development of conveyors, the primitive cranes and hoists of Agricola's day were being developed and refined, and adapted to the use of steam power. Although steam power was first applied in mines for the purpose of pumping, it was not long after 1830 that hoisting engines began to appear. During the remainder of the 19th century, development of large scale construction, of mines, and railroad shops and freight handling brought cranes and hoists almost to their modern state.

In this same period, the wheelbarrow blossomed out into all sorts of wheeled carriers such as factory trucks, baggage trucks and industrial railways.

One more 19th-century invention must be noted—pneumatic conveying. The movement of cotton in a stream of air, based on the action of the ejector, is said to have started about 1867. Shortly after this date, air handling was extended to such products as grain and malt, chiefly by J. K. Williams in the United States. Later the method was adapted to handling coal, ash, ore, sawdust, chemicals, fertilizer, tankage, and other products.

By 1905, there were thus available all the types of materials-handling equipment used today, though generally in much less developed form and not adapted to the special needs of many of the industrial operations now dependent upon them. This adaptation, and the rapid advance of materials-handling devices to their present status as the focus and pacemaker of industrial operations came about with the rapid development of mass production during the last 30 years. Chiefly in automobile factories, but also in many other branches of industry, the last three decades have seen the continued improvement of such equipment as the chain conveyor, the monorail or tramrail, the industrial truck (with its attendant system of skid handling and storage) and a multitude of special conveyors and handling devices. It is only through their use that modern, large scale production methods are economically possible.

CONSTRUCTION MATERIALS

By JAMES A. LEE
Managing Editor, Chem. & Met.

WHILE we have no written records of the chemical engineer of 10,000 or even as recently as 5,000 years ago it is safe to assume that his demands for corrosion- resistant materials of construction were extremely limited; however, he did have need for construction materials of more modest requirements. The engineer of prehistoric times learned to fashion his simple equipment from earth and stone. And later as he became more adept with the use of tools he included wood in his catalog of materials. Glass was another material that was probably used in those very early times since it was available near old lava and volcanic deposits. On authority of early writers we know that it was in use as early as 4400 B.C.

The use of metal in Europe probably goes back about 5,000 years, and in Egypt copper has been traced back to about 3500 B.C. This metal in its natural state serves to link together the stone and metal ages. Hammered copper has been found among Chaldean remains of 4500 B.C., and Petrie has stated that the native copper in the Badarian graves of the Fayum is even more ancient. In the excavations of Ur cast copper objects were found among the possessions of the Sumerians of 3100 B.C.

The bronze age followed the stone age and it began in Europe about 2000 B.C. Brass has been long in use, but is more modern than bronze.

Lead was one of the earliest metals known to man. This heavy gray metal was evidently well known in Biblical times for it is mentioned in Exodus and in other books of the Old Testament. Old lead pipes have been found in Egypt and in the days of the Pharaohs lead was used to glaze pottery, to make solder and ornamental objects. The Assyrians had many uses for the metal, and the hanging gardens of Babylon were floored with sheets of lead soldered together to retain the moisture around the roots of the plants. The architect Vitruvius, who wrote a handbook in 25 B.C., lists the standard sizes of lead pipe ranging in circumference from 5 to 100 in.

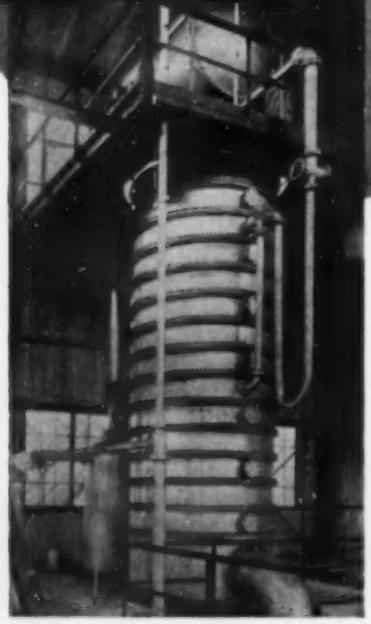
The early use of iron is obscure. Encyclopedia Britannica asserts that in Egypt, Chaldea, Assyria, and China, the so-called iron age reaches far back to perhaps 4,000 years before the Christian era. The belief in the antiquity of iron in Egypt is based mainly on the evidence

Upper left: Wood was the chief construction material in Agricola's time, although lead was used for caldron G

Upper right: Glass, pottery and copper were the chief reliances of the alchemist (Aula Subterranea)

Lower left: All aluminum distilling column in a modern chemical manufacturing plant

Above: Modern stainless steel process cooler



of the pieces of metal found in the Great Pyramid at Gizek and in an early grave at Aleydos. Petrie states that no iron was intelligently produced by an understood process as a regular manufacture before 1200 B.C.

The heat available in the primitive furnace sufficed only to produce a lump of spongy metal, the texture of which became compacted as it was hammered into useful metal. This "wrought" iron could be made by the reduction of ore at a temperature of 800 or 900 deg. C., whereas the melting of iron, to produce "cast" iron, requires a temperature of 1,500 deg., a degree of heat not attainable until the blowing-engine was invented. The first production of cast iron in western Europe was delayed until the fourteenth century; therefore the earliest making of wrought iron is separated from the discovery of the art of casting iron by fully 2,500 years, as Rickard has stated.

The use of iron became common in the early days of the Roman Empire; at that time the smiths used it to make nails, hinges, bolts as well as weapons of warfare. Several foundries were started by the Romans in Sussex shortly before the death of Vespasian in 79 A.D. In the twelfth century a further expansion of the iron industry is evident, and at that time the Forest of Dean became the center of the English iron industry: it was the Birmingham of medieval days.

The date of the first steel making is not known definitely because a stage of transition from wrought iron to steel was inevitable, at first as an accidental consequence of subjecting ordinary iron to carburization when it was reheated on a charcoal forge. The absorption of carbon gave the metal a steel-like quality. As early as the days of Chaucer (1340-1400) Sheffield was known for its manufacture of steel. However, the age of steel is said to have had its real beginning when Bessemer made public his process in 1856.

Just about 100 years ago the first metallic aluminum known was produced by an ingenious application of chemistry. But 50 years passed before Charles Martin Hall of Ohio developed a cheap and convenient method of production. In 1886 he invented a successful electrolytic reduction process and founded the modern aluminum industry. The first works using this process started operation in November 1888 at Pittsburgh.

Nickel has been known for hundreds of years. The Chinese were working a natural alloy of nickel and copper before the Christian era; they called this alloy Pack Fong. But the commercial history of nickel is brief for it never achieved much notice until deposits in New Caledonia were discovered in 1853. For 30 years it existed only as a memory and then the first discovery of ore in place was made near what was known as the Murray mine, about 1883. This find started a rush. The mines in the neighborhood were opened and worked and production of nickel soon became a well-established industry.

Century of Rubber

In 1839, Charles Goodyear discovered the process of vulcanizing soft rubber with sulphur. This discovery led to the development of a process for mixing large quantities of sulphur with rubber and heating the dough to effect conversion into hard rubber. He patented the process in 1851 and a few years later the commercial manufacture of hard rubber started and increased

rapidly to become an important branch of this industry.

In more recent times, the introduction of new materials and the development of improvements and modifications in established materials have followed in rapid succession. Last year the fiftieth anniversary of the development of glass-lined equipment was celebrated by a leading manufacturer. About 30 years ago non-transparent fused silica ware was offered by the English for the first time and a few days later the transparent variety followed. In 1909, Dr. Baekeland developed and patented the phenolformaldehyde synthetic resin, and patents covering modifications of this resin and other types of resin have since followed in every industrial country.

New Materials

Other materials that have been used by chemical engineers for a comparatively brief period of time are carbon, silver, platinum, tantalum and a great variety of stainless steels and non-ferrous alloys. Electroplated and sprayed metals, plymetals, and rubber linings are all among the newer materials of construction.

Among the most important materials in use at the present time are the ferrous alloys. Thum states that chromium steels had been commercial since 1869 when Julius Baur established his works in Brooklyn. Brearly patented the range of chromium between 9 and 16 per cent, and carbon less than 0.7 per cent, knowing that heat treatment was essential to suppress the free carbide and to produce homogeneity, and realizing that over 16 per cent chromium rendered the medium carbon alloys immune to heat treatment, in the sense that they would not harden properly on quenching. Alloys of this sort were commercialized by 1914, when the production of stainless cutlery in Sheffield, England, was made from steel melted in clay pot crucibles. Monypenny states that low-carbon stainless steel was first produced on a commercial scale in June 1920. Much of the credit for heat-resistant iron alloys high in chromium is due to F. M. Becket, who, from 1903 onward, was continuously attacking the problem of producing low-carbon ferrochromium from chrome ores.

Chrome-Nickel Steels

Between the years 1909 and 1912 metallurgists in the laboratories of the Krupp organization in Germany worked with the chromium-nickel steels. This work led to the development and patenting in 1912 of two groups of high chromium-nickel steels. The compositions of these alloys steels were 14 per cent chromium, 1.8 nickel and 0.15 carbon; and 20 chromium, 7 nickel and 0.25 carbon. This early work by Drs. Strauss, Maurer and others led finally to the development of the type of chromium-nickel alloys we know today as 18-8.

CONTROL EQUIPMENT

EDITORIAL STAFF

IN EARLIER PAGES we have seen the panorama of development that has led to today's array of unit operations. In what little space remains it is fitting to examine briefly a few of the parallel developments in measurement and control that have evolved for holding these basic elements in line, for supplementing human senses, and for bringing processes to a desired conclusion. Unfortunately, much of the history of measurement is obscure. Much must be surmised. Little of it is certain before the late 16th century when the rebirth of learning contributed most fully to this as well as to other sciences.

The genesis of all control, whether it be manual or automatic, is measurement. Whatever the variable, man had first to discover a means for measuring it before he could attempt its control. Take, for example, duration—or time—which was one of the first of the variables that he measured successfully. Prehistoric man knew only of day and night. He had a feeling for the passage of time and he may even have observed the movement of shadows, but he was no astronomer. Ancient Egyptians, however, learned to tell time by the sun, then by the flow of sand or of water through an orifice. By the 13th century

Top: A barometer (in glass) of 1861; and another of 80 years ago

Right: Thermometers of Galileo's time and shortly thereafter

Right: Industrial thermometers of about 1890

Below: Patent office model of earliest known recording thermometer, patented in 1875

Circle: An 1893 recorder of Bristol's, one of the earliest of this type

A.D. the first crude clock escapement had been devised and the weight-driven mechanical clock began its gradual displacement of the water clock, the sand glass and the sun dial. Spring drive came during the 16th, and the pendulum during the 17th, centuries. During the next hundred years the clock attained its present form and status as a true precision instrument.

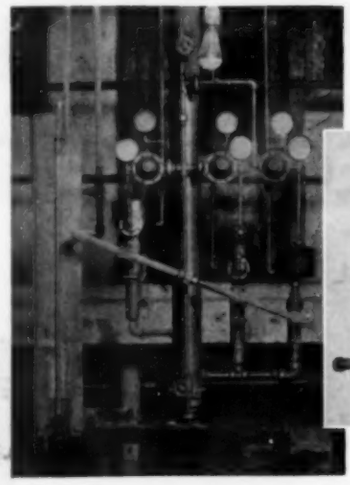
Liquid-flow measurement became important with the early development of hydraulics, much of which was in a fairly clear state in pre-Christian times. Ancient Roman citizens bought their water on the basis of the quantity that would flow through a given pipe—but without reference to head. Not until about 100 B.C. was the effect of head on flow suspected, and not until the work of Torricelli, about 1640, was the square-root relation recognized. Still another hundred years was to pass before the final formulation by Bernoulli of his equation of energies, from which he derived the true hydraulic flow equation, and from which stems our modern flowmeter engineering. Another 50 years saw the development of the Pitot tube, and still another 50 years, the Venturi tube which latter still forms the basis of one of our most important flow measuring methods.

Measurement of temperature doubtless interested the first physician to speculate on the cure of fevers. The thermometer, however, came only with Galileo, in 1597, and did not bear a scale until 1613. Still the instrument was of little scientific value until 230 years later, when Kircher built the first modern instrument, with mercury as the liquid. Another 80 years elapsed before Fahrenheit made the thermometer reliable, giving it also the scale that is known by his name today.

The next stage in temperature measurement dates from Becquerel's use of the Seebeck effect, in 1826, in the construction of the first temperature-measuring thermocouple, an attempt, however, which met with little success. Not until LeChatelier's work, about 1885, did the thermocouple attain any real success. At about the same time, Callender devised an accurate resistance thermometer and in 1892, LeChatelier suggested that radiation measurement be employed for high temperature determinations. The theory of radiation was only then developing, however, and it was 1902 before the two fundamental radiation pyrometer types, the optical and radiation instruments, developed under two scientists, Morse and Féry, respectively.

What has been said here is scarcely adequate introduction for the interesting exhibits of early instruments that adorn these pages. Acknowledgment is due to the concerns that supplied them, particularly, to the Taylor Instrument Cos. who opened their museum for the photographing of suitable types, and supplied much information. Those views not otherwise credited are from the Taylor collection, most of them the developments of companies which later joined the Taylor group. We are indebted to the C. J. Tagliabue Manufacturing Co. and the Bristol Co., both for helpful suggestions and for illustrative material showing early equipment of their manufacture.

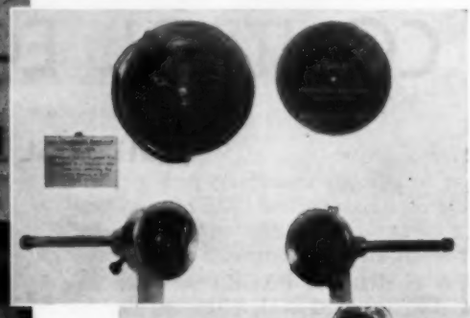
Tag pressure controller of 1900 still in use

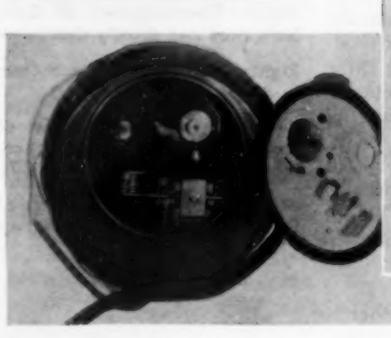


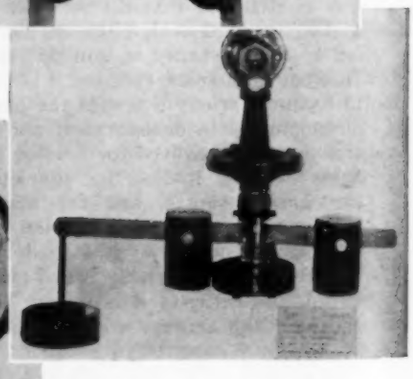
Expansion-stem temperature regulators (1905 and 1910), and a capillary temperature controller of 1914

Temperature regulator controlling steam pressure, about 1912

Time-temperature controller used in rubber manufacture, about 1917

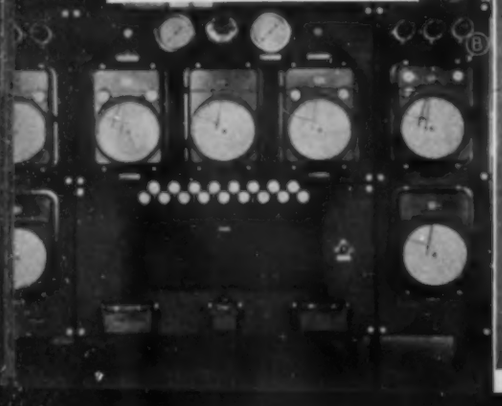




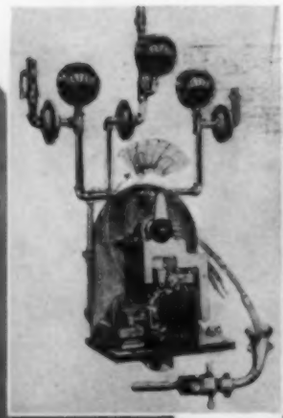


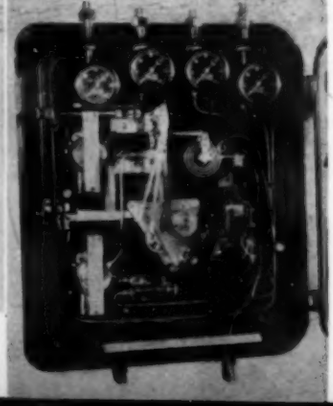
A contrast in temperature control:

Above, a Bristol electric contact thermometer of 1903; and below, one of this company's most recent installations



A contrast in cycle control: Tag time-temperature controllers of 1913 and 1935





Chemical Engineering NEWS

A.I.Ch.E. Announces Plans for Wilmington Sessions

RECENT announcements relative to plans for the twenty-seventh semi-annual meeting of the American Institute of Chemical Engineers call attention to a change in the dates as originally announced. The meeting will open on Monday, May 13, and will continue through May 15. The Hotel duPont, Wilmington, Del., has been selected as official headquarters and registration will open at 8 p.m., Sunday, May 12, for those who may wish to come early.

Every morning of the three-day meeting will be given over to technical sessions. Group luncheons will follow and on Wednesday afternoon an additional technical session will be devoted to the principles of chemical engineering.

Among the papers scheduled for the technical sessions are:

APPLIED SESSIONS

"Semi-Works Organization," by F. C. Vilbrandt, Dept. of Chemical Engineering, Iowa State College.

"How We Use Our Semi-Works," by Charles J. Darlington and C. Chester Ahlum, Jackson Laboratory, E. I. du Pont de Nemours and Co.

"The Manufacturing of Phosphoric Acid by the Electrical Furnace Method," by Harry A. Curtis, Tennessee Valley Authority.

"Precious Metals as Materials of Construction," by Fred E. Carter, Research Department, Baker & Co., Inc., Newark, N. J.

"Frangible Disks as Protection for Pressure Vessels," by Morgan E. Bonyun, Dye Works Engineering Department, E. I. du Pont de Nemours & Co., Penns Grove, N. J.

"Application and Design of Induction Heating for Chemical Process Equipment," by Charles E. Daniels, Engineering Dept., E. I. du Pont de Nemours & Co.

"Sodium—Its Handling on the Industrial Scale—With Examples of Its Use in Chemical Reactions," by P. J. Carlisle, R. & H. Chemicals Dept., E. I. du Pont de Nemours & Co., Niagara Falls, N. Y.

"New Developments in Refractories and New and Unique Materials," by Louis J. Trostel, General Refractories Co., Baltimore, Md.

PRINCIPLES SESSION

"Rate of Absorption of CO_2 in Potassium Carbonate Solutions in a Packed Tower," by B. F. Dodge, Dept. of Chemical Engineering, Yale University.

"Pressure Drop and Loading Velocities in Packed Towers," by A. McLaren White, Dept. of Chemical Engineering, University of North Carolina.

"The Course of Liquor Flow in Packed Towers," by Theodore Baker, Thomas H. Chilton and Harcourt C. Vernon, Experimental Station, E. I. du Pont de Nemours & Co.

"Rate of Absorption of Carbon Dioxide—Variation During Batch Absorption by Caustic Solutions," by Lauren B. Hitchcock, Dept. of Chemical Engineering, University of Virginia.

"The Rate of Absorption of a Pure Gas Into a Still Liquid During Short Periods of Exposure," by Ralph Higbie, Eagle-Picher Lead Co., Joplin, Mo.

"Heat Transmission by Radiation from Non-Luminous Gases. II. Experimental Study of Carbon Dioxide and Water Vapor," by H. C. Hottel and H. G. Mangelsdorf, Massachusetts Institute of Technology; Standard Oil Co. of Louisiana, Baton Rouge, La.

"The Theory of Short Circuiting in Continuous-Flow Mixing Vessels in Series and the Kinetics of Chemical Reactions in Such Systems," by R. B. MacMullin and M. Weber, Jr., Research Laboratory, The Mathieson Alkali Works, Niagara Falls, N. Y.

"Some Phenomena Occurring Within the Boundary Layer at an Interface Between a Solid and a Flowing Fluid," by G. G. Lamb and H. J. Masson, Dept. of Chemical Engineering, New York University.

"Countercurrent Extraction of Potassium and Magnesium Sulphates from Calcined Polyhalite," by John E. Conley, F. Fraas and Everett P. Partridge, U. S. Bureau of Mines, Rutgers University.

On the afternoon of May 13 there will be a visit to the dyeworks of E. I. du Pont de Nemours & Co. In the evening Pierre S. du Pont has invited the members and their guests to inspect his gardens at Longwood and to have supper in his conservatory, which is one of the finest in the world. This will be followed by a display of his illuminated fountains.

On the afternoon of May 14 there will be a choice of plant visits, including oil refineries of the Sun Oil Co. and Pure Oil Co. at Marcus Hook and Socony Vacuum Oil Co., at Paulsboro, the cotton finishing plant of Joseph Bancroft & Sons Co., the Haveg plant, and the plant of the Continental Diamond Fibre Co.

On Wednesday evening there will be a banquet at the Hotel du Pont, followed by dancing.

As referred to in the March issue of *Chem. & Met.*, immediately following the general meeting, the Committee on Chemical Engineering Education, of which Dr. Harry A. Curtis is chairman, will sponsor a symposium on Chemical Engineering Laboratory Design Equipment and Use. This symposium is scheduled for May 16 and May 17 and at the same time the Committee on Student Chapters will sponsor a two-day meeting for student members at Drexel Institute, Philadelphia.

Slight Increase in Sulphur Production Last Year

ACCORDING to a report from the U. S. Bureau of Mines production and shipments of sulphur changed little in 1934 in comparison with 1933. Production of sulphur increased slightly, from 1,406,063 long tons in 1933 to 1,421,473 tons in 1934. Shipments declined from 1,637,368 tons in 1933, valued at about $29,500,000, to 1,613,838 tons in 1934, valued at about $28,900,000. Production of sulphur was reported from California, Louisiana, and Texas.

Texas was again the leading sulphur-producing state with an output in 1934 of 1,187,233 long tons, or 84 per cent of the total for the country. In 1933, Texas produced 1,083,445 tons, 77 per cent of the total. Shipments amounted to 1,302,663 tons in 1934, compared with 1,507,749 tons in 1933. The properties that contributed to the production in 1934 were those of the Duval Texas Sulphur Co. at Palangana Dome, Benavides; Freeport Sulphur Co. at Bryan and Hoskins Mounds, Freeport; and the Texas Gulf Sulphur Co. at Long Point Dome, Long Point, and at Boling Dome, Newgulf.

Production of sulphur in Louisiana decreased from 321,492 long tons in 1933 to 229,830 tons in 1934. Shipments, however, increased from 128,916 tons in 1933 to 307,186 tons in 1934. As in 1933, the Freeport Sulphur Co. and the Jefferson Lake Oil Co., Inc., were the producers.

Electrochemical Society Meets In New Orleans

EDITORIAL STAFF REPORT

MANY MEMBERS of the Electrochemical Society journeyed to New Orleans on March 21 for the three-day annual convention of the organization. The unique attractions of the Creole City accounted for an unusually large attendance of ladies, and the several new chemical developments in Louisiana and the interesting technical program appealed to many men.

Pres. Hiram S. Lukens opened the meeting on Thursday morning and turned the technical session on the alkali-chlorine industry over to Dr. L. D. Vorce who presided. A feature of this session was the address entitled "Salt Domes—The Impetus to Geophysical Prospecting," by Prof. R. A. Steinmayer of Tulane University. The afternoon technical session was presided over by Dr. F. V. Andreae of Anniston, Ala. The final technical session concerned the subject of electrodeposition. Dr. Lukens presided. Abstracts of the technical papers appeared in the March issue of *Chem. & Met.*, pages 148 and 149. Discussion of the papers will appear in the May issue.

On Friday evening the members of the Electrochemical Society were invited to a joint meeting sponsored by the Louisiana-Mississippi Section of the American Institute of Chemical Engineers, the Louisiana Engineering Society and the Louisiana Section of the American Chemical Society. Dr. Lukens delivered his presidential address and George G. Earle, former superintendent of the Sewerage and Water Board, discussed some of the difficult problems encountered in the water supply and drainage system of New Orleans. Formal announcement was made that Dr. Joseph R. Heard, Jr., of Winnfield, La., was selected by the committee of award on the 1934 prize to young authors as the most deserving of the young authors competing for this prize.

One of the highlights of the meeting was the visit to the sulphur development at Grand Ecaille, in Plaquemine Parish, of the Freeport Sulphur Co. The group making the trip was taken by bus to Port Sulphur and there transferred to speed boats in which they completed the trip through the ten-mile canal. The members of the Society on reaching Grand Ecaille were guests of the Freeport organization at luncheon. After the luncheon Dr. Ralph L. Miller, entomologist of the company, discussed the importance of sulphur in agriculture. They then inspected the mining operation where they saw the Frasch process in use.

James H. Critchett

Hiram S. Lukens

During the annual business meeting on Thursday the new officers of the Society were installed. James H. Critchett, vice-president of Union Carbide and Carbon Research Laboratories, New York, is the newly elected president. Other officers for 1935-36 are H. S. Lukens, past-president; Alexander Lowy, R. L. Baldwin, G. W. Heise, J. D. Edwards, Duncan MacRae and D. A. MacInnes, vice-presidents; S. D. Kirkpatrick, O. W. Storey, T. F. Bailey, L. R. Westbrook, Sherlock Swann, J. J. Mulligan, W. S. Landis, S. Skowronski and A. K. Graham, managers; R. M. Burns, treasurer; and Colin G. Fink, secretary.

Announcement was made that Frank J. Tone, president of the Carborundum Co. at Niagara Falls, had been awarded the Edward Goodrich Acheson medal and $1,000 prize which accompanies it, for his outstanding accomplishments in electrothermics. Dr. Tone's early career and education centered around electrical engineering. He became associated in 1885 with Dr. Acheson in the development of silicon carbide and artificial graphite, and since 1899 he has directed his company's activities. Dr. Tone is a former president of the Society. Presentation of the awards will be made in October during the Fall meeting.

The splendid program for the meeting was arranged by the local committee headed by Prof. Charles S. Williamson, of the chemical engineering department at Tulane University and ably assisted by R. P. Walton, George E. Schneider and others.

The Fall meeting of the Society will be held at the New Willard Hotel, Washington, D. C., October 10 to 12.

Industry Leaders Will Aid Chemical Exposition

IN connection with the Fifteenth Exposition of Chemical Industries to be held at Grand Central Palace, New York, Dec. 2-7 it is announced that the Exposition Advisory Committee will include distinguished representatives from all of the leading chemical organizations. This year's presentation will be directed by the International Exposition Co. Members of the Exposition Advisory Committee are: A. D. Little, chairman, Arthur D. Little, Inc.; Raymond F. Bacon, consulting engineer; L. H. Baekeland, honorary professor chemical engineering, Columbia University; Wm. B. Bell, president, Manufacturing Chemists Assn.; J. V. N. Dorr, president, The Dorr Co.; A. E. Marshall, president, American Institute of Chemical Engineers; Henry B. Faber, consulting chemist; John M. Alverez, president, Salesmen's Assn. of American Chemical Society; Williams Haynes, president, *Chemical Industries;* Charles H. Herty, industrial consultant; H. E. Howe, editor, *Industrial and Engineering Chemistry;* James H. Critchett, president, The Electrochemical Society; Sidney D. Kirkpatrick, editor, *Chemical & Metallurgical Engineering;* Roger Adams, president, American Chemical Society; L. H. Marks, president, The Chemists Club; W. T. Read, Rutgers University; H. J. Schnell, manager, *Oil, Paint & Drug Reporter;* T. B. Wagner, consulting chemist; R. Gordon Walker, vice-president, Oliver United Filters, Inc.; M. C. Whitaker, consulting chemist; and Fred W. Payne and Charles F. Roth, co-managers of the exposition.

NEWS FROM WASHINGTON

By PAUL WOOTON

Washington Correspondent of Chem. & Met.

UNCLE SAM'S alphabetic agencies in Washington would all like to outlive their present terms as fixed by emergency legislation of the last Congress. This accounts for the flock of measures providing for continuing legislation now being aggressively pressed in both houses of Congress. Not only N.R.A. and P.W.A. but a half dozen other New Deal bodies are dependent on new legislation for mere continuance beyond May or June.

Still another group of emergency agencies is standing in line at Congressional doorways asking for added authority. A.A.A. legislation is particularly in the limelight and this has considerable importance for chemical process industry. Some of the provisions contemplated would extend the rights of the agricultural administrators well into the field of secondary processing of products of the farm. Some think that the proposed new law might even allow Secretary Wallace to study the books of textile, leather, and like manufacturers whose primary raw material comes from the land or the range.

T.V.A., much curtailed by the need for compliance with the injunction of Federal Judge Grubb at Birmingham, is also seeking enlarged authority. Its Board is asking that Congress make even more explicit the instruction that T.V.A. go into business with respect to power, fertilizer, and other industrial products. Thus, so Board member Lilienthal explains, the courts will only have to pass upon the constitutionality of the question and not be at all in doubt as to whether Congress intends Uncle Sam to be a business man of many affairs in the Valley.

There is most noticeable in Congressional hearing rooms now a disposition to criticize the extension in time and the enlargement of authority of the New Deal agencies. Ultimately the President is likely to get enactment of all of the major points which he puts on his "must list." But if he makes his "must list" too long it may break down and many of the very important items, viewed from the standpoint of managers of alphabetic activity, will, therefore, fall by the wayside.

Court decisions finally settling the scope of New Deal authority were expected in many fields this Spring. Hence there was more than a tempest in a teapot over the Department of Justice withdrawal of the Belcher Lumber case just as the Supreme Court was about to give it final attention. Critics, of course, have interpreted this act as implying a fear on the part of the Administration that its activities are not defensible in the courts. The Administration naturally counters that it did not wish this particular case tried now because the record there had not been adequately prepared for final review.

Probably the critics are right, at least to the extent that the Administration certainly will not, if it can possibly avoid it, risk a final decision on the constitutionality of N.R.A., P.W.A., A.A.A, or other major agency until after Congress adjourns. The Executive Departments wish Congress to extend these agencies, even to enlarge their authority, so that cases now pressing may be made moot. They thus anticipate a safe opportunity for two-year continuance even though ultimately some of the legislation may be ruled unconstitutional. The Belcher case delay was quite adequate to accomplish this purpose of postponing decision until after Congress adjourns. The announcement made early in April that N.R.A. was now pressing another case for Supreme Court decision is not inconsistent with this policy nor does it represent a reversal of plan.

Uncle Sam evidently intends to begin tariff trading according to the rules of that game observed elsewhere in the world. Official notice of this came on the occasion of the promulgation of the trade agreement with Belgium.

This notice was pointedly directed at Germany, Italy, and several other Continental European nations, as well as Canada. Immediately the restriction is imposed that certain named countries, Canada, Netherlands, Spain, Switzerland, and Liechtenstein, shall have the benefit of the Belgian tariff concessions for the period of six months only. The benefits would extend longer only if the United States nationals are accorded full import privileges into those countries which are now denied because of discriminatory quotas or trade restrictions.

More broadly the announcement means that such nations as France must stop discriminating against United States products, must eliminate obnoxious quotas. They must resume, in fact, most-friendly-nation relations or Uncle Sam will abrogate the most-favored-nation treaty. Most observers in Washington do not expect abandonment of these treaties. They believe that mere suggestion of that action will suffice to restore to United States exports equal rights abroad. If such consequence does not become evident it is likely that the whole scheme of tariff trading as now practiced will break down.

On behalf of the Manufacturing Chemists Association, C. A. Higgins, vice-president of the Hercules Powder Co., appeared before the Committee on Education and Labor to oppose passage of the Wagner Labor Disputes Bill. Mr. Higgins stated that the Hercules Powder Co. and its wholly owned subsidiary, the Paper Makers Chemical Corp., operates 32 manufacturing plants, located in practically every section of the United States, and at present employs approximately 3,200 pay roll workers. Some of these plants are small, employing less than 20 men; others are larger, having in some cases more than 600 individuals on the pay roll.

He stated that manufacturers were in favor of the purposes cited in the Bill, but were definitely of the opinion that the Bill, as written, will not only fail to accomplish the intended objective, but will have the opposite effect, that it will increase the causes of labor disputes and deprive the worker of his individual rights to which he, as a free American citizen, is entitled.

He added: "The Bill clearly endorses and makes compulsory the principle of majority rule for purposes of collective bargaining. While this is the principle on which our government is based, it is beset with practical political difficulties when applied to many industrial establishments in this country.

"For example, many of our southern plants employ a large number of colored workers. In some cases such workers are in the majority. It is not difficult to forsee the possible consequences of any attempt to apply and enforce the majority rule provisions of the Wagner Bill at plants where such conditions prevail.

"The rights of minorities are given little thought in the Bill as drawn. Section 8 states that if the majority of employees so desire, it may be a condition of employment that all employees must be members of such organization as is representative of such a majority. This means that every worker within such a unit may have to pay tribute and be subject to the rulings of an organization perhaps far removed from the scene of his employment, and whose interest in his direct and individual welfare may be remote.

A.C.S. Completes Plans For Tercentenary

ATTENTION is being focused on the American Chemical Industry Tercentenary which will be celebrated the week of April 22 at New York. The general headquarters will be at the Hotel Pennsylvania, while the division of paint and varnish will be located at the Hotel Governor Clinton and special registration facilities will be provided for the rubber group at the Hotel New Yorker. Arrangements have also been made to accommodate some of the 5,000 chemical engineers and chemists who are expected to attend the meeting at the Hotel McAlpin.

The program includes over 500 technical papers on a wide variety of subjects of interest to chemists and chemical engineers and visits to 40 chemical plants in greater New York.

The Nichols medal dinner and meeting will be held at the Hotel Pennsylvania on Tuesday evening. Dr. Arthur W. Hixson, chairman of the convention and of the New York section, will preside. Rev. Eugene P. Burke of the Arts faculty of the University of Notre Dame will speak on "The Personal Side of Dr. Nieuwland's Life," E. R. Gridgwater of the Rubber Chemicals Division of E. I. duPont de Nemours & Co. will discuss "Practical Applications of Dr. Nieuwland's Work," J. M. Weiss, chairman of the medal jury of award, will make the presentation and Dr. J. A. Nieuwland will speak on "Basic Research on Unsaturated Hydrocarbons."

The chemical industries symposium will be held on Wednesday afternoon at the Pennsylvania. Roger Adams, president of the American Chemical Society, will make the introductory address. Alfred H. White, professor of chemical engineering at the University of Michigan, will speak on "The Scientific Foundations of the American Chemical Industries. Lammot DuPont, president of E. I. duPont de Nemours & Co., will follow with an address entitled "Human Wants and the Chemical Industries"; William B. Bell, chairman of the board of the American Cyanamid & Chemical Corp., will speak on "Recovery—by Alchemy or Chemistry?", and Thomas Midgley, Jr., vice-president of the Ethyl Gasoline Corp., will use as his subject, "The Rôle of Chemistry in the Next Hundred Years."

The convention banquet will be held on the evening of the same day at the Hotel Waldorf-Astoria. The program will have such speakers as the Hon. Francis P. Garvan, president of the Chemical Foundation, who will serve as toastmaster; the Hon. Pat Harrison, United States Senator from Mississippi, and the Hon. J. W. Wadsworth, representative from New York.

CALENDAR

AMERICAN CHEMICAL SOCIETY, New York, week of Apr. 22.

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS, spring meeting, Wilmington, Del., May 13-15.

AMERICAN PETROLEUM INSTITUTE, mid-year meeting, Tulsa, Okla., May 14-16.

AMERICAN ASSOCIATION OF CEREAL CHEMISTS, annual meeting, Denver, June 4.

CANADIAN CHEMICAL ASSOCIATION, annual meeting, Kingston, June 4-6.

AMERICAN ELECTRO-PLATERS' SOCIETY, annual meeting, Bridgeport, Conn., June 10-14.

AMERICAN SOCIETY FOR TESTING MATERIALS, annual meeting, Detroit, June 24-28.

TECHNICAL ASSOCIATION OF THE PULP AND PAPER INDUSTRY, fall meeting, Atlantic City, week of Sept. 16.

ELECTROCHEMICAL SOCIETY, semi-annual meeting, Washington, D. C., Oct. 10-12.

EXPOSITION OF CHEMICAL INDUSTRIES, New York, week of Dec. 2-7.

DuPont Will Produce Rayon In Argentina

ANNOUNCEMENT has been made by E. I. duPont de Nemours & Co. that it will expand its activities in the Argentine. With its associates in that country and a French group represented by the Comptoir des Textiles Artificielles, a new company will be formed to be known as "Ducilo" S A Productora de Rayon which will engage in the manufacture and sale of viscose rayon. Construction of a modern plant, employing approximately 1,000 employees and located near Buenos Aires, will be started shortly.

Dr. W. M. Allen to Receive First Lilly Award

FIRST award of Eli Lilly & Co., for developments in biological chemistry, comprising a bronze medal and $1,000 in cash will be made to Dr. Willard M. Allen of the University of Rochester. Dr. Allen was selected for the honor because of his work in the preparation and chemical purification of progestin.

The presentation will be made at the eighty-ninth meeting of the American Chemical Society in New York during the week of April 22.

Monsanto to Absorb the Swann Corp.

THE board of directors of both The Swann Corp., in which Monsanto acquired a controlling interest in 1933, and Monsanto Chemical Co. approved a contract and will recommend to their respective stockholders the merging of The Swann Corp. into Monsanto. If ratified the stockholders of The Swann Corporation will receive one share of Monsanto common for each four and one half shares of Swann common.

The Swann Corporation has headquarters in Birmingham and a plant in Anniston, Alabama. A Swann subsidiary corporation, The Provident Chemical Company, has a plant in St. Louis, Mo., for the manufacture of mono-calcium and di-sodium phosphate; another subsidiary, the Wilckes, Martin, Wilckes Co., has a plant at Camden, N. J., where lamp black, bone ash and phosphate salts are produced. The Anniston operations are electrochemical and produce phosphoric acid and its derivatives, calcium carbide, ferro phosphorus and abrasives.

Edgar M. Queeny, president of Monsanto, stated that as the operations of The Swann Corp. are non-competitive with Monsanto the acquisition increases the diversity of Monsanto's income and provides new avenues for development in the electrochemical field.

The Swann Corp. has gross assets of about $5,500,000 and a capitalization of 508,000 shares of no par common stock, and $704,000 of subsidiary 6 per cent preferred stock.

Monsanto also has acquired the Atlantic Chemical Co. of Billerica, Mass., manufacturers of heavy chemicals. This company will be consolidated with the Merrimac division.

Code Authority Approved for Used Machinery Trade

THE Code Authority for the Used Machinery and Equipment Distributing Trade has been approved by the National Recovery Administration. The members approved include M. D. Galbreath of Marr-Galbreath Machinery Co., Pittsburgh; L. E. Emerman, L. E. Emerman Co., Chicago; A. Goldman, Riverside Machinery Depot, Detroit; J. E. Middleton, L. F. Seyfert's Sons, Inc., Philadelphia; C. A. Simmons, Simmons Machine Tool Co., Albany; J. E. Launder, Independent Electric Machinery Co., Kansas City; and J. L. Lucas, J. L. Lucas & Son, Bridgeport, Conn.

At the organization meeting held March 23, Mr. Galbreath was elected Chairman of the Authority, Mr. Middleton, Vice Chairman, C. L. McDonald, of St. Louis, Treasurer, and Ralph S. Davis, of Pittsburgh, Executive Secretary.

NAMES *in the News*

SELWYN G. BLAYLOCK, vice-president and general manager of Consolidated Mining and Smelting Co. of Canada, Trail, B. C., and president of the Canadian Institute of Mining & Metallurgy, has been awarded the Institute's Platinum Medal for distinguished contribution to his country's mineral industry.

C. V. HOLLAND resigned his position with the Sulco Laboratories March 1 and is now chemical engineer for Merck & Co., Rahway, N. J.

P. S. WILCOX, president of Tennessee Eastman Corp., has been elected to the board of directors of the Eastman Kodak Co.

W. A. HAUCK has been appointed assistant to the president of Lukens Steel Co., Coatesville, Pa.

H. L. BLENSSLI, who received his Ph.D. degree last June from the department of chemical engineering of Columbia University, is now associated with the Bogalusa Paper Co., Bogalusa, La.

DONALD G. FOULKE, has been appointed graduate assistant in the School of Chemistry at Rutgers University. Mr. Foulke recently graduated from Juniata College.

J. K. RUMMEL has resigned from Babcock & Wilcox Co., which company he served as chemical engineer in the research and service departments. He has accepted a position in charge of the laboratories of the Shanghai Power Co., 95 Nankin Road, Shanghai, China.

HERBERT LEVINSTEIN has been elected president of the Institute of Chemical Engineers. Born in 1878 and educated at Rugby, Owens College, Manchester and Zurich, Dr. Levinstein has devoted 25 years to the dyestuff industry. He became managing director of the British Dyestuffs Corp. in 1918.

BYRON B. MORTON, formerly plant metallurgist at the Baton Rouge refinery of the Standard Oil Co. of Louisiana, has joined the staff of the development and research department of the International Nickel Co.

Frank J. Tone

FRANK J. TONE, president of the Carborundum Co., Niagara Falls, has been awarded the Edward Goodrich Acheson medal and the $1,000 prize which accompanies it by the Electrochemical Society. Dr. Tone is a former president of the society. He has made outstanding contributions on industrial electrochemistry, notably silicon. Dr. Tone's early career and education centered around electrical engineering. He became associated in 1885 with Acheson in the development of silicon carbide and artificial graphite. Since 1899 he had directed his company's activities.

MARTIN H. ITTNER has been nominated for the presidency of the New York Chemists' Club for 1935-36. Other officers will be Arthur W. Hixson, resident vice-president; Victor G. Bloede, non-resident vice-president; John Johnston, suburban vice-president; Robert T. Baldwin, secretary; S. J. White, treasurer; S. D. Kirkpatrick and Clark E. Davis, trustees for a three-year term.

HUNTER PENDLETON, professor of chemistry at Virginia Military Institute, will retire from active duty in June. Colonel Pendleton has been actively associated with the Institute for 45 years, having been in his present position since 1890.

W. O. SWAN, of the chemical department at Southwestern College, Memphis, Tenn., has been appointed successor to Colonel Pendleton at V.M.I.

ERLE G. HILL has joined Lukens Steel Co., Coatesville, Pa., as director of research. In 1920, he became an associate professor of metallurgy at the University of Pittsburgh, serving there for ten years, during which time he also functioned as consultant for various companies. He resigned in 1930 to accept a research fellowship at Mellon Institute, remaining in that work until he joined the steel company.

MAX Y. SEATON has been transferred to the New York headquarters of Westvaco Chlorine Products Corp.

JOHN W. MCCOY, general manager of the explosives department of the E. I. duPont de Nemours & Co., has been elected a member of the company's board of directors, and has also been made a vice-president and member of the executive committee. He has served as general manager of the department since August, 1929.

EDWARD B. YANCY succeeds John W. McCoy as general manager of the explosives department of the duPont company.

OBITUARY

CARL DUISBERG, chairman of the I. G. Farbenindustrie, died March 18, at his home in Leverkusen, near Cologne, Germany. Dr. Duisberg was 73 years of age. He studied at the universities of Jena, Gottingen, Munich, and Strasbourg. On completing his studies he went to work in the laboratory of Prof. Hans von Pechmann and a few years later he was engaged by an Elberfeld dye manufacturer. Henceforth he devoted all his efforts to the development of dyes. His firm formed one of the principal units of the organization that is now known as I. G. Farbenindustrie.

RICHARD ZIESING, zinc refining expert for the Grasselli Chemical Co. until his retirement several years ago, died March 9, in his home at Vero Beach, Fla., of a heart attack. He was 75 years old.

GEORGE F. RICHMOND, head of the chemical laboratories of Colgate-Palmolive-Peet Co., died March 21 in the Presbyterian Hospital, Newark, N. J., of pneumonia. Dr. Richmond became associated with the company 15 years ago. Previously he had been connected with Antoine Chiris Co., and Givandan-Delawanna Co.

HOWARD BENNETTE, president of the Western Refiners Association and a director of the American Petroleum Institute, died March 10, in the Mayo Clinic, Rochester, Minn.

Chemical ECONOMICS

EMPLOYMENT and pay rolls continued their gains despite a less than seasonal increase in industrial production during February, the Federal Reserve Board reported in its monthly business survey.

The board set industrial activity at 89 per cent of the 1923-25 average in February, compared with 91 per cent in January and 83 per cent in February, 1934.

Factory employment, the survey said, however, "increased between the middle of January and the middle of February by more than the usual seasonal amount, reflecting substantial increases in working forces in the automobile, machinery, iron and steel, and wearing apparel industries and smaller increases in many other lines.

Because of the wide variety of chemicals affected, the automotive industry is of particular interest to chemical manufacturers. And the rate of activity in automobile manufacture has been quite high throughout the first quarter of this year with a total of about 1,100,000 units turned out.

Consumption of crude rubber by manufacturers in the United States for February amounted to 43,187 long tons, which compares with 47,103 long tons for January. February consumption shows a change of 8.31 per cent under January and 6.4 per cent over February, 1934, according to the Rubber Manufacturers' Association. Consumption for February, 1934, was reported to be 40,609 long tons.

Deliveries of silk to mills in March were reported at 44,347 bales, which represents a gain over deliveries in the preceding month and also a gain over the corresponding month last year. The cotton branch of the textile industry made a good showing in the quarter, but the outlook favors some cutting down in productive activities because stocks of finished goods have been piling up. In fact, the National Industrial Recovery Board, acting upon recommendations of its recently created textile planning committee, has authorized the cotton textile code authority to make temporary adjustments in the maximum hours of operation in groups of the industry which are unable to find suitable markets for their products.

In reporting on the state of business in the corn refining field, two of the large factors report that the first two months of this year brought very little change from the like period of 1934. Competition from tapioca is keen with imports running to unusually large volumes. The industry has presented to NRA a report and a petition asking for relief under Section 3-A of NRA, which has been referred to the Tariff Commission. The industry asked for limitation of imports based upon some fair average quantity which would permit industries that require tapioca to get their material without penalty which would be involved in a tariff. In addition to the application to the Tariff Commission, there has been introduced in Congress a bill providing for a processing tax of 2½ cents a pound on the first domestic use of tapioca, sago and casaba.

Conditions remain favorable for the sale of fertilizer this season. Tag sales to date are reported to have surpassed those of a year ago and the underlying conditions such as high prices for live stock and farm products are conducive to an expansion in the use of fertilizers.

The action of the International Rubber Regulation Committee in reducing the quotas of rubber for export resulted in a higher market for rubber. Under the present quotas, exports from producing sections for this year will reach about 750,000 tons, while last year such shipments amounted to 1,014,000 tons. The proposed rate of shipments would run more than 170,000 tons below last year's actual world consumption. Hence stocks in consuming markets are bound to be reduced by the end of the year unless there is a radical decline in consuming requirements.

Freight carloadings of the 29 principal commodities are expected to total 4,605,737 cars in the second quarter of 1935, compared with 4,603,241 actual loadings for the same commodities in the corresponding period last year.

Eight of the Thirteen Shippers' Regional Advisory Boards estimate an increase in the loadings for the second quarter of 1935 compared with the same period in 1934 while five estimate a decrease.

For coal and coke a reduction of 4.7 per cent in the second quarter compared with the preceding year is estimated due to the uncertainty that exists in the bituminous coal regions over the wage situation.

Of the 29 commodities included in the estimate increases are expected in 19 and decreases in 10. Increases over the second quarter of last year are estimated as follows: salt, 1.6 per cent; petroleum and products, 3.8 per cent; cement, 6.8 per cent; brick and clay products, 12.2 per cent; lime and plaster, 8 per cent; fertilizers, 10.3 per cent; and chemicals and explosives, 12.9 per cent.

United States production of benzol, estimated by the Bureau of Mines from the production of coke at byproduct ovens known to recover this commodity, amounted to 12,382,000 gal. in the first two months of 1935 compared with 10,987,000 gal. in the January-February, 1934, period. The term "benzol" represents crude and refined benzol plus motor benzol.

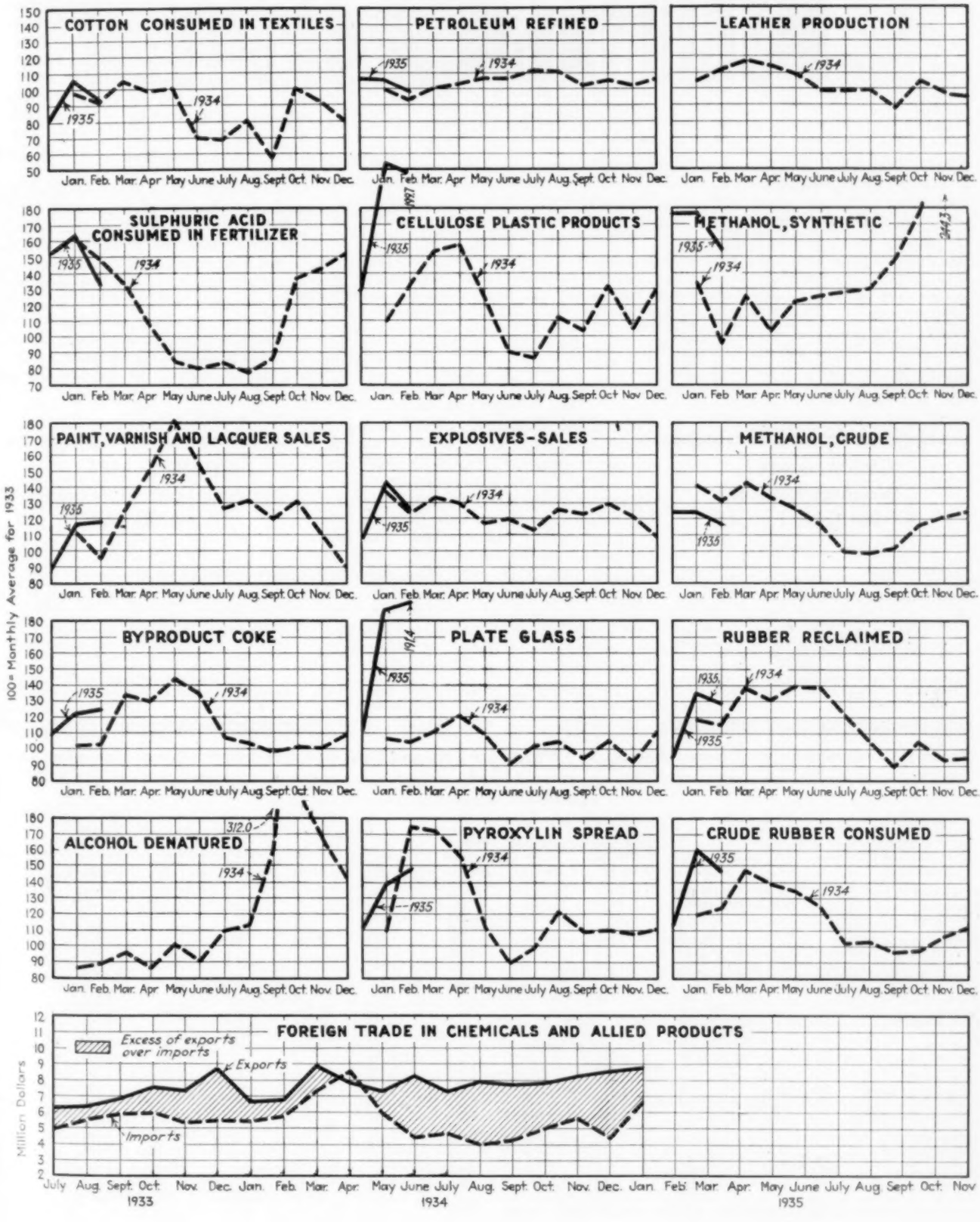
Uncertainty surrounding general business was instrumental in bringing about a declining trend in prices. Here again, chemicals followed the general tendency and the undertone was weaker despite the fact that most of the important heavy chemicals maintained a steady position and alcohol went counter to the general trend and was marked up in price.

Production and Consumption Data for Chemical-Consuming Industries

	Feb. 1935	Feb. 1934	Jan.-Feb. 1935	Jan.-Feb. 1934	Per Cent of gain Jan.-Feb. 1935 over Jan.-Feb. 1934
Production					
Automobiles, No.	340,544	231,707	633,309	388,614	85.9
By product coke, 1,000 tons	2,781	2,493	5,583	4,969	18.9
Glass containers, 1,000 gr.	2,639	2,600	5,574	5,370	3.8
Plate glass, 1,000 sq.ft.	13,723	7,441	27,088	15,048	80.0
Methanol crude, gal.	300,008	337,983	615,991	698,805	12.1*
Methanol, synthetic, gal.	1,126,799	690,961	2,429,970	1,670,647	45.4
Nitrocellulose plastics, 1,000 lb.	1,476	1,152	2,941	2,100	40.0
Cellulose acetate plastics, 1,000 lb.	922	436	1,926	794	142.7
Paper board, tons	249,299	223,366	515,353	453,677	13.6
Pyroxylin spread, 1,000 lb.	4,444	4,318	8,658	7,601	13.9
Rubber reclaimed, tons	10,072	8,934	20,537	18,172	13.0
Steel barrels, No.	355,220	521,950	745,679	1,184,243	37.0*
Consumption					
Cotton, 1,000 bales	478	477	1,025	985	4.0
Silk, bales	41,732	39,021	89,175	79,963	11.5
Wool, 1,000 lb.	51,616	34,348	109,986	70,316	56.4
Explosives, 1,000 lb.	26,019	25,584	55,166	54,088	2.0
Crude rubber, tons	43,187	40,609	90,290	79,893	13.0

*Per cent of decline.

TRENDS OF PRODUCTION AND CONSUMPTION



The MARKETS

FOR THE most part, there has been a fairly steady withdrawal of chemicals from producing points so far this year. Reports, with reference to the last month, have revealed spotty conditions with some industries apparently cutting down on their activities while others have gone along better than had been anticipated. The textile trade as a whole has shown a tendency to slow up from the rate of activity established earlier in the year. On the other hand it had been expected that call for raw materials from the plate glass and rubber trades would be reduced last month while actual developments revealed that there had been little if any drop in demand from those directions.

A public hearing on proposed changes in price-basing and price reporting under the code of fair competition for the linseed oil industry has been called by the Secretary of Agriculture for April 22 at the Mayflower Hotel, Washington, D. C.

In effect the proposed system calls for price reporting on an f.o.b. basis. There would be three area classifications—primary markets, towns where crushing mills are located; secondary markets, where bulk stocks are carried; and rural markets, all cities and towns located outside primary and secondary markets.

Prices in the industry have been reported on an eight-zone basis, hinging largely on freight rates from shipping points. Approval of the Secretary of Agriculture is required before the new proposal can go into effect. He has called the hearing in view of widespread questions from buyers of linseed oil.

The Treasury Department has devised a form which is to be followed by manufacturers of ethyl acetate in reporting daily shipments. The new form is merely to secure a uniform method of reporting shipments.

Five domestic producers of salt cake have filed a petition with N.R.A for relief from the intense competition of imports which it is alleged are threatening to destroy the possibility of domestic compliance with N.I.R.A. labor provisions. The petitioners ask for relief in some sort of quota on imports, control within limits of import in recent previous years, or a fee on imports that would be equivalent to a compensatory duty. The rate of $5 per ton of crude salt cake is suggested.

The Research and Planning Division continuing its investigation will reach findings on which N.I.R.B. administrative action will be taken. If N.I.R.B. decides that relief should be accorded, the matter will go to the President and if he concurs will occasion a Tariff Commission study. Ultimately the President will be able to order relief on the basis of Tariff Commission recommendations under the provisions of N.I.R.A.

CHEM. & MET. Weighted Index of CHEMICAL PRICES

Base = 100 for 1927

This month	**87.53**
Last month	87.63
April, 1934	88.93
April, 1933	84.30

Xylol was in a strong position owing to small supplies and alcohol was marked up because of higher producing costs. With these exceptions the market showed a tendency to sell off and the weighted index declined slightly.

CHEM. & MET. Weighted Index of Prices for OILS AND FATS

Base = 100 for 1927

This month	**94.47**
Last month	99.02
April, 1934	57.13
April, 1933	42.01

Cottonseed oil weakened appreciably during the month and most of the other oils were affected by the position of the leader. Tallow also declined in price with an easier undertone to the general market for fats.

Factory Consumption of Primary Animal and Vegetable Fats and Oils, by Classes of Products, Calendar Year 1934

(Quantities in thousands of pounds)

KIND	TOTAL	Compounds and Vegetable Shortenings	Oleomargarine	Other Edible Products	Soap	Paint and Varnish	Linoleum and Oilcloth	Printing Inks	Miscellaneous Products	Loss Including Foots
Total	4,028,003	1,214,742	214,132	292,466	1,474,415	329,894	67,811	15,544	259,143	159,856
Cottonseed oil	1,377,437	1,058,733	54,778	155,343	2,702	18	.....	29	3,298	102,536
Peanut oil	14,999	8,837	2,744	854	147	.....	.....	1	49	2,367
Coconut oil	589,602	9,045	123,678	78,636	341,124	37	.....	2	2,128	34,952
Corn oil	61,094	1,895	4	38,630	6,268	404	.....	.....	4,157	9,736
Soybean oil	20,907	2,735	24	509	1,354	10,451	2,843	59	2,109	823
Olive oil, edible	2,372	.....	.....	2,188	51	.....	.....	.....	133	.....
Olive oil, inedible	8,975	.....	.....	.....	1,953	.....	.....	.....	7,022	.....
Sulphur oil or olive foots	30,738	.....	.....	.....	30,411	2	.....	.....	325	.....
Palm-kernel oil	22,601	.....	.....	4,608	16,516	.....	.....	.....	32	1,445
Rapeseed oil	10,366	122	.....	.....	994	76	17	.....	9,157	.....
Linseed oil	258,483	.....	.....	.....	1,022	205,743	32,108	12,606	7,004	.....
China wood oil	105,978	.....	.....	.....	35	88,184	12,854	1,660	3,245	.....
Perilla oil	16,108	.....	.....	.....	.....	9,898	4,481	582	1,147	.....
Castor oil	20,188	.....	.....	.....	1,786	2,299	317	62	15,724	.....
Palm oil	191,738	16,717	66	538	154,704	3	.....	10	*14,835	4,865
Sesame oil	7,403	4,720	.....	1,408	466	.....	.....	.....	36	773
Sunflower oil	11,756	901	.....	1,003	7,142	631	1,909	.....	40	130
Other vegetable oils	5,479	1,626	2	627	1,836	260	.....	37	790	301
Lard	14,260	2,635	7,486	3,837	24	.....	.....	3	184	91
Edible animal stearin	28,703	21,517	3,478	2,474	452	.....	.....	.....	782	.....
Oleo oil	26,137	764	21,872	108	85	.....	.....	.....	3,308	.....
Tallow, edible	78,909	73,416	.....	1,703	1,098	.....	.....	1	2,558	133
Tallow, inedible	717,368	.....	.....	.....	662,858	105	.....	8	54,254	143
Grease	240,154	.....	.....	.....	142,782	76	.....	375	96,270	651
Neat's-foot oil	4,561	.....	.....	.....	61	16	.....	1	4,483	.....
Marine animal oils	35,207	304	.....	.....	33,996	37	.....	5	838	27
Fish oils	126,480	10,775	.....	.....	64,548	11,654	13,282	103	25,235	883

*Includes 12,057 thousand pounds reported by the tin and terne plate industry.

Current PRICES

The following prices refer to round lots in the New York market. Where it is the trade custom to sell f.o.b. works, quotations are given on that basis and are so designated. Prices are corrected to April 12.

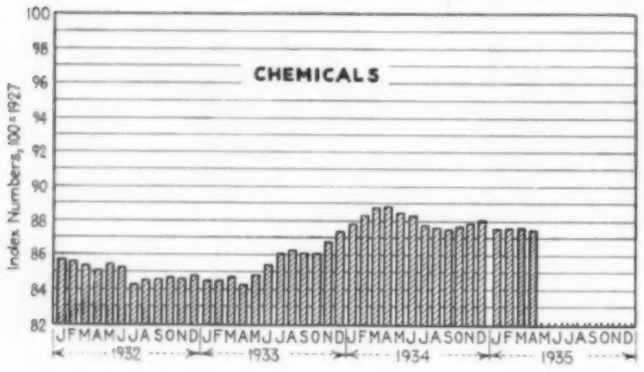
Industrial Chemicals

	Current Price	Last Month	Last Year
Acetone, drums, lb.	$0.12 -$0.12½	$0.12 -$0.12½	$0.11 -$0.11½
Acid, acetic, 28%, bbl., cwt.	2.40 - 2.65	2.40 - 2.65	2.90 - 3.15
Glacial 99%, drums	8.25 - 8.50	8.25 - 8.50	10.02 -10.27
U. S. P. reagent, c'bys	10.52 -10.77	10.52 -10.77	10.52 -10.77
Boric, bbl., lb.	.04¼- .05	.04¼- .05	.04¼- .05
Citric, kegs, lb.	.28 - .31	.28 - .31	.28 - .31
Formic, bbl., lb.	.11 - .11½	.11 - .11½	.11 - .11½
Gallic, tech., bbl., lb.	.60 - .65	.60 - .65	.60 - .65
Hydrofluoric 30% carb., lb.	.07 - .07½	.07 - .07½	.07 - .07½
Lactic, 44%, tech., light, bbl., lb.	.12 - .12½	.12 - .12½	.11½ - .12
22%, tech., light, bbl., lb.	.06½- .07	.06½- .07	.05½- .06
Muriatic, 18° tanks, cwt.	1.00 - 1.10	1.00 - 1.10	1.00 - 1.10
Nitric, 36°, carboys, lb.	.05 - .05½	.05 - .05½	.05 - .05½
Oleum, tanks, wks., ton	18.50 -20.00	18.50 -	18.50 -20.00
Oxalic, crystals, bbl., lb.	.11¼- .12¼	.11¼- .12¼	.11¼- .12¼
Phosphoric, tech., c'bys., lb.	.09 - .10	.09 - .10	.09 - .10
Sulphuric, 60°, tanks, ton	11.00 -11.50	11.00 -11.50	11.00 -11.50
Sulphuric, 66°, tanks, ton	15.50 -	15.50 -	15.50 -
Tannic, tech., bbl., lb.	.23 - .35	.23 - .35	.23 - .35
Tartaric, powd., bbl., lb.	.24 - .25	.24 - .25	.26 - .26½
Tungstic, bbl., lb.	1.40 - 1.50	1.40 - 1.50	1.40 - 1.50
Alcohol Amyl	-	-	-
From Pentane, tanks, lb.	.15 -	.143-	.15 -
Alcohol Butyl, tanks, lb.	.13 -	.12 -	.095-
Alcohol, Ethyl, 190 p'f., bbl., gal	4.27½-	4.15½-	4.15½-
Denatured, 190 proof			
No. 1 special, dr., gal.	.36 -	.346-	.346-
No. 5, 188 proof, dr., gal.	.35½-	.34 -	.34 -
Alum, ammonia, lump, bbl., lb.	.03 - .04	.03 - .04	.03 - .04
Chrome, bbl., lb.	.04½- .05	.04½- .05	.04½- .05
Potash, lump, bbl., lb.	.03 - .04	.03 - .04	.03 - .04
Aluminum sulphate, com., bags cwt.	1.35 - 1.50	1.35 - 1.50	1.35 - 1.50
Iron free, bg., cwt.	1.90 - 2.00	1.90 - 2.00	1.90 - 2.00
Aqua ammonia, 26°, drums lb.	.02½- .03	.02½- .03	.02½- .03
tanks, lb.	.02½- .02¼	.02½- .02¼	.02½- .02¼
Ammonia, anhydrous, cyl., lb.	.15½- .16	.15½- .16	.15½- .16
tanks, lb.	.04½-	.04¼-	.04¼-
Ammonium carbonate, powd tech., casks, lb.	.08 - .12	.08 - .12	.08 - .12
Sulphate, wks., cwt.	1.20 -	1.20 -	1.25 -
Amylacetate tech., tanks, lb.	.142-	.142-	.145-
Antimony Oxide, bbl., lb.	.11½- .12	.10½- .12	.08½- .10
Arsenic, white, powd., bbl., lb.	.03½- .04	.03½- .04	.04 - .04½
Red, powd., kegs, lb.	.15½- .16	.15½- .16	.15 - .15½
Barium carbonate, bbl., ton	56.50 -58.00	56.50 -58.00	56.50 -58.00
Chloride, bbl., ton	72.00 -74.00	74.00 -75.00	74.00 -75.00
Nitrate, cask, lb.	.08½- .09	.08½- .09	.08½- .09
Blanc fixe, dry, bbl., lb.	.03½- .04	.03½- .04	.03½- .04
Bleaching powder, f.o.b., wks. drums, cwt.	1.90 - 2.00	1.90 - 2.00	1.85 - 2.00
Borax, grain, bags, ton	40.00 -45.00	40.00 -45.00	40.00 -45.00
Bromine, cs., lb.	.36 - .38	.36 - .38	.36 - .38
Calcium acetate, bags	2.00 -	2.00 -	3.00 -
Arsenate, dr., lb.	.06 - .07	.06 - .07	.06 - .07
Carbide drums, lb.	.05 - .06	.05 - .06	.05 - .06
Chloride, fused, dr., del., ton	20.00 -33.00	20.00 -33.00	17.50 -
flake, dr., del., ton	22.00 -35.00	22.00 -35.00	19.50 -
Phosphate, bbl., lb.	.07½- .08	.07½- .08	.07½- .08
Carbon bisulphide, drums, lb.	.05½- .08½	.05½- .06	.05½- .06
Tetrachloride drums, lb.	.05½- .08½	.05½- .06	.05½- .06
Chlorine, liquid, tanks, wks., lb.	2.00 -	2.00 -	.0185-
Cylinders	.05½- .06	.05½- .06	.05½- .06
Cobalt oxide, cans, lb.	1.25 - 1.30	1.25 - 1.30	1.35 - 1.40
Copperas, bgs., f.o.b. wks., ton	14.00 -15.00	14.00 -15.00	14.00 -15.00
Copper carbonate, bbl., lb.	.08½- .16	.08½- .16	.08½- .16
Cyanide, tech., bbl., lb.	.37 - .38	.37 - .38	.39 - .40
Sulphate, bbl., cwt.	3.85 - 4.00	3.85 - 4.00	3.85 - 4.00
Cream of tartar, bbl., lb.	.16½ .17	.16½- .17	.18½- .19
Diethylene glycol, dr., lb.	.16½- .20½	.16½- .20½	.14 - .16
Epsom salt, dom., tech., bbl., cwt.	2.10 - 2.15	2.10 - 2.15	2.10 - 2.15
Imp., tech., bags, cwt.	2.00 - 2.10	2.00 - 2.10	2.00 - 2.10
Ethyl acetate, drums, lb.	.08½-	.08½-	.08¼-
Formaldehyde, 40%, bbl., lb.	.06 - .07	.06 - .07	.06 - .07
Furfural, dr., contract, lb.	.10 - .17½	.10 - .17½	.10 - .17½
Fusel oil, crude, drums, gal.	.75 -	.75 -	.75 -
Refined, dr., gal.	1.25 - 1.30	1.25 - 1.30	1.25 - 1.30
Glaubers salt, bags, cwt.	1.00 - 1.10	1.00 - 1.10	1.00 - 1.10
Glycerine, c.p., drums, extra, lb.	.14 - .14½	.14 - .14½	.12½- .13
Lead:			
White, basic carbonate, dry casks, lb.	.06½-	.06½-	.06½-
White, basic sulphate, sck., lb.	.06 -	.06 -	.06 -
Red, dry, sck., lb.	.06½-	.06 -	.08 -
Lead acetate, white crys., bbl., lb.	.10½- .11	.10½- .11	.10½- .11
Lead arsenate, powd., bbl., lb.	.09 - .10	.09 - .10	.09 - .13
Lime, chem., bulk, ton	8.50 -	8.50 -	8.50 -
Litharge, pwd., csk., lb.	.05 -	.05 -	.07 -
Lithophone, bags, lb.	.04½- .05	.04½- .05	.04½- .05
Magnesium carb., tech., bags, lb.	.06 - .06½	.06 - .06½	.06- .06½
Methanol, 95%, tanks, gal.	.33 -	.33 -	.33 -
97%, tanks, gal.	.34 -	.34 -	.34 -
Synthetic, tanks, gal.	.35½-	.35½-	.35½-
Nickel salt, double, bbl., lb.	.12½- 13	.12½- .13	.11½- .12
Orange mineral, csk., lb.	.09 -	.09 -	.10½-
Phosphorus, red, cases, lb.	.44 - .45	.44 - .45	.45 - .46
Yellow, cases, lb.	.28 - .32	.28 - .32	.28 - .32
Potassium bichromate, casks, lb.	.07½- .08½	.07½- .08½	.07½- .08½
Carbonate, 80-85%, calc. csk., lb	.07 - .07½	.07 - .07½	.07 - .07½
Chlorate, powd., lb.	.08½- .09	.09½- .10	.09½- .10
Hydroxide (c'stic potash) dr., lb.	.06½- .06½	.06½- .06½	.07½- .08
Muriate, 80% bgs., ton	22.00 -	22.00 -	37.15 -
Nitrate, bbl., lb.	.05½- .06	.05½- .06	.05½- .06
Permanganate, drums, lb.	.18½- .19	.18½- .19	.18½- .19
Prussiate, yellow, casks, lb.	.18 - .19	.18 - .19	.18 - .19
Sal ammoniac, white, casks, lb.	.04½- .05	.04½- .05	.04½- .05
Salsoda, bbl., cwt.	1.00 - 1.05	1.00 - 1.05	1.00 - 1.05
Salt cake, bulk, ton	13.00 -15.00	13.00 -15.00	13.00 -15.00
Soda ash, light, 58%, bags, contract, cwt.	1.23 -	1.23 -	1.23 -
Dense, bags, cwt.	1.25 -	1.25 -	1.25 -
Soda, caustic, 76%, solid, drums, contract, cwt.	2.60 - 3.00	2.60 - 3.00	2.60 - 3.00
Acetate, works, bbl., lb.	.04½- .05	.04½- .05	.04½- .05
Bicarbonate, bbl., cwt.	1.85 - 2.00	1.85 - 2.00	1.85 - 2.00
Bichromate, casks, lb.	.05½- .06½	.05½- .06½	.05½- .06½
Bisulphate, bulk, ton	15.00 -16.00	14.00 -16.00	14.00 -16.00
Bisulphite, bbl., lb.	.03½- .04	.03 - .04	.03 - .04
Chlorate, kegs, lb.	.06½- .06½	.06½- .06½	.06½- .06½
Chloride, tech., ton	12.00 -14.75	12.00 -14.75	12.00 -14.75
Cyanide, cases, dom., lb.	.15½- .16	.15½- .16	.15½- .16
Fluoride, bbl., lb.	.07½- .08	.07½- .08	.07½- .08
Hyposulphite, bbl., lb.	2.40 - 2.50	2.40 - 2.50	2.40 - 2.50
Metasilicate, bbl., cwt.	3.25 - 3.40	3.25 - 3.40	3.25 - 3.40
Nitrate, bags, cwt.	1.275-	1.275-	1.35 -
Nitrite, casks, lb.	.07½- .08	.07½- .08	.07½- .08
Phosphate, dibasic, bbl., lb.	.022- .024	.022- 0.24	.021- .023
Prussiate, yel. drums, lb.	.11½- .12	.11½- .12	.11½- .02
Silicate (40° dr.) wks. cwt.	.80 - .85	.80 - .85	.80 - .85
Sulphide, fused, 60-62%, dr., lb.	.02½- .03½	.02½- .03	.02½- .03
Sulphite, cyrs., bbl., lb.	.02½- .02½	.02½ .02½	.03 - .03½
Sulphur, crude at mine, bulk, ton	18.00 -	18.00 -	18.00 -
Chloride, dr., lb.	.03½- .04	.03½- .04	.03½- .04
Dioxide, cyl., lb.	.07 - .07½	.07 - .07½	.07 - .07½
Flour, bag, cwt.	1.60 - 3.00	1.60 - 3.00	1.55 - 3.00
Tin Oxide, bbl. lb.	.51 -	.52 -	.57 -
Crystals, bbl., lb.	.37½-	.36 -	.40½-
Zinc chloride, gran., bbl., lb.	.05 - .06	.05½- .06	.05½- .06
Carbonate, bbl., lb.	.09½- .11	.09½- .11	.09½- .11
Cyanide, dr., lb.	.36 - .38	.38 - .42	.38 - .42
Dust, bbl., lb.	.059- .07	.057- .07	.07 - .07½
Zinc oxide, lead free, bag, lb.	.05½-	.05½-	.06½-
5% lead sulphate, bags, lb.	.05½-	.05½-	.06½-
Sulphate, bbl., cwt.	2.75 - 3.00	2.75 - 3.00	3.00 - 3.25

Oils and Fats

	Current Price	Last Month	Last Year
Castor oil, No. 3, bbl., lb.	$0.09½-$0.10	$0.09½-$0.10	$0.09½-$0.10
Chinawood oil, bbl., lb.	.15 -	.12 -	.08½-
Coconut oil, Ceylon, tanks, N. Y. lb.	.05½-	.06½-	.02¾-
Corn oil crude, tanks, (f.o.b. mill), lb	.09½-	.11 -	.04½-
Cottonseed oil, crude (f.o.b. mill), tanks, lb.	.09½-	.10½-	.04¾-
Linseed oil, raw car lots, bbl., lb.	.09½-	.09½-	.093-
Palm, casks, lb	.05¾-	.05¾-	.03½-
Palm Kernel, bbl., lb.	nom.	nom.	.04¾-
Peanut oil, crude, tanks (mill), lb.	.09½-	.10½-	.05 -
Rapeseed oil, refined, bbl., gal.	.46 - .47	.50 - .52	.42 - .43
Soya bean, tank, lb.	.10 -	.10 -	.06½-
Sulphur (olive foots), bbl., lb.	.08½-	.08½-	.06½-
Cod, Newfoundland, bbl., gal.	.35 -	.36 -	nom.
Menhaden, light pressed, bbl., lb.	.069-	.065-	.051-
Crude, tanks (f.o.b. factory), gal.	.35 -	.30 -	.20 -
Grease, yellow, loose, lb.	.06½-	.06½-	.03½-
Oleo stearine, lb.	.10½-	.12 -	.05½-
Red oil, distilled, d.p. bbl., lb.	.09½-	.08½-	.07 -
Tallow, extra, loose, lb.	.06½-	.07 -	.03½-

CHEM. & MET.'S WEIGHTED PRICE INDEXES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98
96
94
92
90
88
86
84
82
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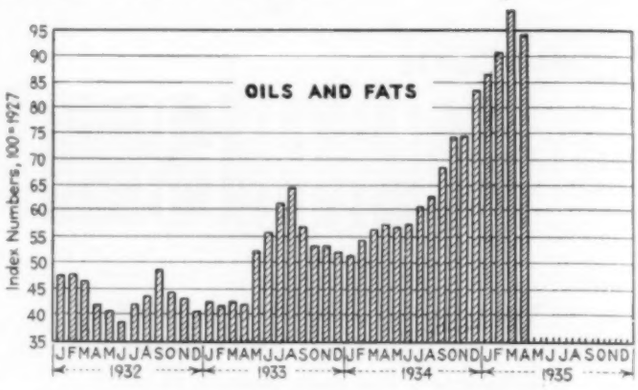
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95
90
85
80
75
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55
50
45
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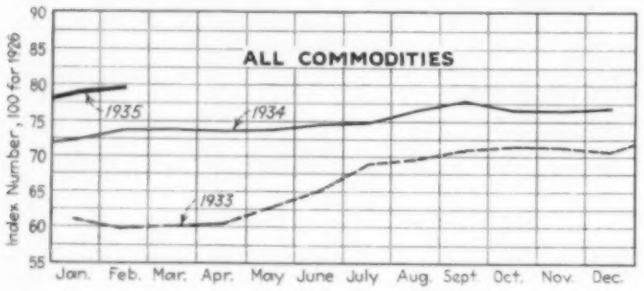
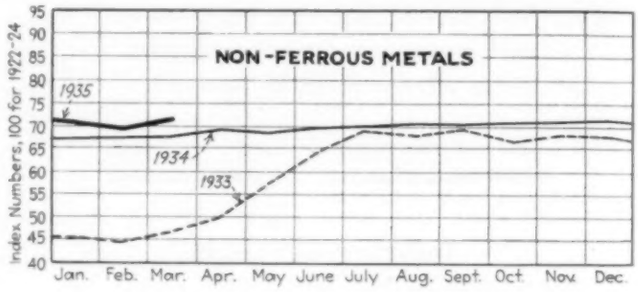




Coal-Tar Products

	Current Price	Last Month	Last Year
Alpha-naphthol, crude, bbl., lb.	$0.60 -$0.65	$0.60 -$0.65	$0.60 -$0.62
Refined, bbl., lb.	.80 - .85	.80 - .85	.80 - .85
Alpha-naphthylamine, bbl., lb	.32 - .34	.32 - .34	.32 - .34
Aniline oil, drums, extra, lb.	.14½- .15	.14½- .15	.14½- .15
Aniline salts, bbl., lb.	.24 - .25	.24 - .25	.24 - .52
Benzaldehyde, U.S.P., dr., lb.	1.10 - 1.25	1.10 - 1.25	1.10 - 1.25
Benzidine base, bbl., lb.	.65 - .67	.65 - .67	.65 - .67
Benzoic acid, U.S.P., kgs, lb.	.48 - .52	.48 - .52	.48 - .52
Benzyl chloride, tech., dr., lb.	.30 - .35	.30 - .35	.30 - .35
Benzol, 90% tanks, works, gal.	.15 - .16	.15 - .16	.20½- .21
Beta-naphthol, tech., drums, lb.	.22 - .24	.22 - .24	.22 - .24
Cresol, U.S.P., dr., lb.	.11 - .11½	.11 - .11½	.11- .11½
Cresylic acid, 97%, dr., wks., gal	.42 - .43	.42 - .43	.50 - .51
Diethylaniline, dr., lb.	.55 - .58	.55 - .58	.55 - .58
Dinitrophenol, bbl., lb.	.29 - .30	.29 - .30	.29 - .30
Dinitrotoluen, bbl. lb.	.16 - .17	.16 - .17	.16 - .17
Dip oil 25% dr., gal.	.23 - .25	.23 - .25	.23 - .25
Diphenylamine, bbl., lb.	.38 - .40	.38 - .40	.38 - .40
H-acid, bbl., lb.	.65 - .70	.65 - .70	.65 - .70
Naphthalene, flake, bbl., lb.	.05½- .06½	.05½- .06½	.06 - .07
Nitrobensene, dr., lb.	.08½- .09	.08½- .09	.08½- .10
Para-nitraniline, bbl., lb.	.51 - .55	.51 - .55	.51 - .55
Phenol, U.S.P., drums, lb.	.14½- .15	.14½- .15	.14½- .15
Picric acid, bbl., lb.	.30 - .40	.30 - .40	.30 - .40
Pyridine, dr., gal.	1.10 - 1.15	1.10 - 1.15	.90 - .95
Resorcinal, tech., kegs, lb.	.65 - .70	.65 - .70	.65 - .70
Salicylic acid, tech., bbl., lb.	.40 - .42	.40 - .42	.40 - .42
Solvent naphtha, w.w., tanks, gal.	.26 -.....	.26 -.....	.26 -.....
Tolidine, bbl., lb.	.88 - .90	.88 - .90	.88 - .90
Toluene, tanks, works, gal.	.30 -.....	.30 -.....	.30 -.....
Xylene, comm., tanks, gal.	.30 -.....	.26 -.....	.26 -

Miscellaneous

	Current Price	Last Month	Last Year
Barytes, grd., white, bbl., ton.	$22.00-$25.00	$22.00-$25.00	$22.00-$25.00
Casein, tech., bbl., lb.	.12½- .14	.13 - .14	.12½- .13
China clay, dom., f.o.b mine, ton	8.00 -20.00	8.00 -20.00	8.00 -20.00
Dry colors:			
Carbon gas, black (wks.), lb.	.04 - .20	.04 - .20	.04 - .20
Prussian blue, bbl., lb.	.36½- .38	.36½- .38	.35 - .36
Ultramine blue, bbl., lb.	.06 - .32	.06 - .32	.06 - .32
Chrome green, bbl., lb.	.26 - .27	.26 - .27	.26 - .27
Carmine red, tins, lb.	4.00 - 4.40	4.00 - 4.40	4.00 - 4.40
Para toner, lb.	.80 - .85	.80 - .85	.80 - .85
Vermilion, English, bbl., lb.	1.56 - 1.58	1.56 - 1.58	1.60 - 1.63
Chrome yellow, C. P., bbl., lb.	.15 - .16	.15 - .15½	.15 - .15½
Feldspar, No. 1 (f.o.b. N.C.), ton	6.50 - 7.50	6.50 - 7.50	6.50 - 7.50
Graphite, Ceylon, lump, bbl., lb.	.07 - .08½	.07 - .08½	.07 - .08½
Gum copal Congo, bags, lb.	.09 - .10	.09 - .10	.06 - .08
Manila, bags, lb.	.09 - .10	.09 - .10	.16 - .17
Damar, Batavia, cases, lb.	.15½- .16	.15½- .16	.16 - .16½
Kauri No. 1 cases, lb.	.20 - .25	.20 - .25	.45 - .48
Kieselguhr (f.o.b. N.Y.), ton.	50.00 -55.00	50.00 -55.00	50.00 -55.00
Magnesite, calc, ton.	50.00 -.....	50.00 -.....	40.00 -.....
Pumice stone, lump, bbl., lb.	.05 - .07	.05 - .08	.05 - .07
Imported, casks, lb.	.03 - .40	.03 - .40	.03 - .35
Rosin, H., bbl.	5.65 -.....	5.95 -.....	6.25 -.....
Turpentine, gal.	.52½-.....	.55½-.....	.58½-.....
Shellac, orange, fine, bags, lb.	.27 -.....	.27 -.....	.26 - .27
Bleached, bonedry, bags, lb.	.20 - .21	.21 - .22	.29 - .31
T. N. bags, lb.	.14 - .16	.14 - .16	.21 - .22
Soapstone (f.o.b. Vt.), bags, ton	10.00 -12.00	10.00 -12.00	10.00 -12.00
Talc, 200 mesh (f.o.b. Vt.), ton.	8.00 - 8.50	8.00 - 8.50	8.00 - 8.50
300 mesh (f.o.b Ga.), ton.	7.50 -10.00	7.50 -10.00	7.50 -11.00
225 mesh (f.o.b N Y.), ton.	13.75 - ..	13.75 -.....	13.75 -.....

INDUSTRIAL NOTES

THE KOPPERS CONSTRUCTION CO., Pittsburgh, Pa., after May 1 will have its New York office at 90 Broad St.

CONTINENTAL-DIAMOND FIBRE CO., Newark, Del., announces that its subsidiary, the Haveg Corp., has opened an office in the Palmolive Bldg., Chicago with A. J. Fischer in charge.

CROCKER-WHEELER ELECTRICAL MFG. CO., Ampere, N. J., has elected B. D. Christian to the office of vice-president. Mr. Christian has been identified with the company for twenty-one years, the last nine years in the position of general sales manager.

READING IRON CO., Philadelphia, has formed a commercial research department to furnish information regarding the relative merits of the various kinds of pipe in specific uses.

KARL M. HERSTEIN has opened an office in the Chemists Bldg., New York, where he will continue his work as consulting chemist.

THE EAGLE-PICHER SALES CO., Cincinnati, has opened a completely equipped insulation divisional headquarters in the Temple Bar Bldg. with M. J. Washburn as divisional manager.

THE IRONTON FIRE BRICK CO., Ironton, Ohio, has appointed Neville & Cleary, Inc., Atlanta, Ga., as exclusive sales representatives for Tennessee, North Carolina, South Carolina, Alabama, Georgia, and Florida.

NATIONAL ALLOY STEEL CO., Blawnox, Pa., has appointed Horace T. Potts Co., E. Erie Ave. and D St., Philadelphia as representative for the districts of Philadelphia and Baltimore.

UNITED CARBON CO., Charleston, W. Va., has formed a subsidiary, United Carbon, Inc., to take over its carbon black plants in five states.

LUKENS STEEL CO., Coatesville, Pa., announces that Walter E. Barnes has been appointed assistant to F. H. Gordon, vice-president in charge of sales.

New CONSTRUCTION

Where Plants Are Being Built in Process Industries

	Current Projects		Cumulative 1935	
	Proposed Work and Bids	Contracts Awarded	Proposed Work and Bids	Contracts Awarded
New England	$75,000	$400,000	$561,000	$75,000
Middle Atlantic	113,000	178,000	670,000	709,000
South	58,000	294,000	1,237,000	470,000
Middle West	3,395,000	.....	5,489,000	916,000
West of Mississippi	3,308,000	109,000	3,776,000	715,000
Far West	128,000	4,400,000	1,331,000	350,000
Canada	1,186,000	.....	4,733,000	70,000
Total	$8,263,000	$5,381,000	$17,797,000	$3,305,000

PROPOSED WORK BIDS ASKED

Asphalt Products Plant—Jamestown Macadam Co., R. J. Granger, Gen. Mgr., 828 Monroe St., Jamestown, N. Y., has leased the Central Ave. pier of the Erie R. R. Co. at Dunkirk Harbor, Lake Erie, also purchased a two acre site of land, and plans the construction of a plant for the manufacture of asphalt products. Estimated cost with equipment $28,500.

Carbon Paper Factory, etc.—Remington-Rand, Inc., Railroad Ave., Bridgeport, Conn., is receiving bids for the construction of a 1 story, 80x300 ft. factory for the manufacture of carbon paper and typewriter ribbons, at Railroad and Wordin Aves. Estimated cost $75,000.

Cement Plant—Wabash Portland Cement Co., Osborn, Ohio, will soon award general and separate contracts for alterations to and reconditioning its cement plant. J. Etchells, 927 St. Paul St., Baltimore, Md., Engr. $30,000.

Distillery—Penn Maryland Corp., Peoria, Ill., or c/o National Distillers Corp., 120 Bway., New York, N. Y., plans to replace the blending and rectifying plant at Peoria recently destroyed by fire. Estimated cost $150,000.

Factory — International Fibre Board Ltd., Gatineau, Que., Can., plans to construct an addition to its factory at Gatineau near Hull, Que. Charles Southgate is manager. $40,000.

Gas Plant—City, Dunkirk, N. Y., plans the construction of a municipal gas plant. Albert G. Waters, City Engr. Estimated cost to exceed $28,000.

Gas Plant—C. H. Withers & Co., Regina, Sask., Can., plan to construct a gas plant at North Battleford, Alta., Can., involving piping from Unity Valley, a distance of 53 mi. to cost $440,000 and distribution lines in North Battleford to cost $150,000.

Glass Factory — Ford Motor Co., Dearborn, Mich., plans to modernize and recondition its glass manufacturing plant at River Rouge, Detroit, for manufacturing 90 in. wide glass, ¼-in. thick by continuous process. Project includes melting and annealing furnaces and grinding and finishing equipment. Estimated cost $3,000,000.

Factory—Knox Glass Associates, Inc., c/o Oil City Glass Bottle Co., Oil City, Pa., will remove its present equipment from Sheffield, Pa., to Oil City and build a 1 story, 20x175 ft. addition. Machinery and equipment will be installed for decorating glassware.

Factory—United Decorating Co., c/o Kenneth Kurtz, Weston, W. Va., plans the construction of a 1 story plant here to be used for decorating glassware.

Lime Products Plant — Washington-Idaho Lime Products Co., Spokane, Wash., and Orofino, Idaho, plans to construct a plant at Orofino and install equipment. $100,000.

Medicinal Preparations — Alvinorr Products, Ltd., G. G. Dando, Mgr., Galt, Ont., Can., plans to construct a plant for the manufacture of medicinal preparations. Estimated cost $40,000.

Oil Refinery—Bell Refining Co., Ltd., Calgary, Alta., Can., plans to construct a refinery to have a daily capacity of 2000 bbl. of crude oil, and a 175,000 gal. tank.

Oil Refinery—Georgetown Oil Mill, c/o T. C. Smith, Secy., Georgetown, Tex., plans to construct a 60 ton, 60x120 ft. seedhouse, and is in the market for seed cleaner, hammer mill and conveying machinery.

Oil Refinery—North Star Oil Co., Ltd., Edmonton, Alta., Can., has purchased a site here and plans to construct a refinery. Estimated cost $40,000.

Oil Refinery—Pacific Oil Co., Ltd., Pointe Aux Trembles, Que., Can., plans the construction of an oil refinery. $350,000.

Oil Refinery—Petroleum Conversion Co., 90 West St., New York, N. Y., plans to rehabilitate the refinery at Texas City, Tex., which has been idle for ten years. $30,000.

Oil Refinery—Shell Petroleum Co., Shell Bldg., Houston, Tex., plans to recondition its refinery here. $200,000.

Oil Refinery—Texas Co., c/o G. L. Noble, Vice Pres., Port Arthur, Tex., plans extensions to its refinery, including new stills and considerable new machinery and equipment. Estimated cost $3,000,000.

Oil Refinery—Turpentine & Rosin Factors Co., Savannah, Ga., plans to construct a refinery, stills and turpentine works with storage facilities at Statesboro, Ga. Estimated cost to exceed $30,000.

Oxygen Factory—Stuart Oxygen Co., 211 Bay St., San Francisco, Calif., is having plans prepared by Ellison & Russell, Engrs., Pacific Bldg., San Francisco, for the construction of a 1 story, 48x137½ ft. factory for the manufacture of oxygen on Bay St. near Powell St.

Paper Mill—Corporation, c/o E. L. Kurth, Lufkin, Tex., contemplates the construction of paper and newsprint mills. Estimated cost to exceed $50,000.

Pottery Plant—Scio Ohio Pottery Co., Scio, O., is having plans prepared by Ladd-Cronin Engineering Co., Minerva, O., for a new circular kiln at its plant. $25,000.

Refractories Plant—General Refractory Products Ltd., A. E. Hildes, Gen. Mgr., Toronto, Ont., Can., plans the construction of a plant for the manufacture of refractory brick, face brick, building tile, etc., at Kapuskasing, Ont. Estimated cost $100,000.

Tin Plate Mill—Dominion Foundries & Steel, Ltd., Depew St., Hamilton, Ont., Can., is having plans prepared by Fred Prack, Archt., 1316 Piggott Bldg., Hamilton, for a tin plate mill to include tinning unit and warehouse, pickle building and boiler house. $50,000.

Warehouse—Baltimore Pure Rye Distilling Co., Dundalk, Md., is having plans prepared for a 2 story, 90x150 ft. warehouse on Sollers Point Rd. C. H. Osborn, 222 West Franklin St., Baltimore is architect.

Warehouses—Hiram Walker, Peoria, Ill., are having plans prepared by Smith, Hinchman & Grylls, Archts., Marquette Bldg., Detroit, Mich., for the construction of three warehouses, in connection with distillery plant. $150,000.

Warehouse — James Walsh Distilling Co., Lawrenceburg, Ind., plans the construction of a 5 story (20,000 bbl.) distillery warehouse. Estimated cost $40,000.

CONTRACTS AWARDED

Brick Kiln — Binghamton Brick Co., Binghamton, N. Y., is building a brick kiln, tunnel type, 300 ft. long. Estimated cost $50,000.

Chemical Factory — Grasselli Chemical Co., 116 Ferry St., St. Louis, Mo., awarded general contract for alterations and additions to its factory to Schnur-Miller Construction Co., 119 North 7th St., St. Louis. Estimated cost $28,500.

Chemical Factory—National Aniline & Chemical Co., Abbott Rd., Buffalo, N. Y., awarded contract for addition to factory to Metzger Construction Corp., 429 Carlton St., Buffalo.

Distillery—Bonnie Bros., 30th and Bank Sts., Louisville, Ky., awarded general contract for distillery including drying building, boiler house and warehouse to H. G. Whittenberg, 2212 Lowell Ave., Louisville. Estimated cost $175,000.

Gas Plant—City, Andalusia, Ala., awarded contract for gas mixing and storage plant and distribution system, including 1 Butane-Air gas mixing plant, to A. Blair, First National Bldg., Montgomery, Ala., $64,929.

Gas Plant—Gas Oil Products Co., Inc., Willard Shreffler, Supt., Lucinda, Pa., will construct a liquid gas plant to produce natural gas, butane, propane, methane, etc., to be marketed in heavy containers in liquid form. Equipment to be installed includes two 48 ft. fractioning towers, each weighing 48 tons, and six 100 hp. gas engines. Work will be done by day labor and separate contracts. In addition to above owner plans immediate drilling of 100 gas wells, each 1,100 to 1,200 ft. in depth to secure supply of natural gas to operate plant.

Chemical Laboratory—Trinity College, 115 Vernon St., Hartford, Conn., awarded contract chemistry laboratory, including classrooms, auditorium and astronomy departments, to A. F. Peaslee, Inc., 15 Lewis St., Hartford. Estimated cost $400,000.

Laboratory—U. S. Department of Agriculture, Washington, D. C., awarded contract laboratory, office building, etc., at U. S. Piedmont Experimental Station, Statesville, N. C., to Gilbert Engineering Co., Statesville, $53,987.

Paint Factory—Norris Paint & Varnish Co., 5163 Easton Ave., St. Louis, Mo., awarded contract for addition to factory to Harry Goldberg, c/o owner. Estimated cost $30,000.

Paper Mill—St. Helen's Pulp & Paper Co., St. Helens, Ore., awarded contract for addition to paper mill to George H. Buckler Co., Lewis Bldg., Portland. Estimated cost $100,000.

Pulp Mill—Weyerhaeuser Timber Co., Everett, Wash., awarded contract for pulp mill to have a daily output of 400 tons of paper, to Alloway & Goerg, Hutton Bldg., Spokane, Wash. Estimated cost $4,000,000.

Bulk Starch Plant—Penick & Ford Co., Cedar Rapids, Ia., and 420 Lexington Ave., New York, N. Y., awarded contract for 1 story bulk starch packing plant to Lightner Bros., Cedar Rapids. $50,000.

Pressure Stills—Standard Oil Co., of California, 225 Bush St., San Francisco, Calif., will reconstruct pressure stills at its refinery at Richmond, Calif. Work will be done by day labor. Estimated cost $300,000.

History of Chemical Industry Is One of Progress

WHILE there may be much of historic interest in tracing the evolution of the domestic chemical industry from its primitive stages to date, there is more of practical value in a comparison based on developments in recent years which may indicate the lines along which progress has been most prominent.

Taking the government classification of "Chemicals and Allied Products" as representing the industry, census data for 1914 demonstrate that pre-war production of chemical products had reached a volume which deserved high rank among domestic industries. The totals for 1914, perhaps show the industry in too favorable a light compared with those for 1919 and later years because the 1914 figures include returns for production of malt and vinous liquors which, necessarily were omitted throughout the prohibition period.

Variables, such as different raw materials purchased and changes in unit values, must be taken into consideration in a comparison of the industry in different years where the comparison is based purely on valuations. A fair idea of the trend in chemical production, however, may be obtained from the following data showing cost of materials and value of products for the years enumerated:

	Cost of Materials, $1,000	Value of Products $1,000
1914	$762,608	$1,667,267
1919	1,550,395	2,939,692
1921	1,022,489	1,840,964
1923	1,316,282	2,472,610
1925	1,374,950	2,651,375
1927	1,409,190	2,855,979
1929	1,579,431	3,289,289
1931	1,255,459	2,650,635
1933	968,473	2,117,513

In one respect the census data reflect a downward trend, the number of establishments in 1914—including those engaged in the manufacture of malt and vinous liquors—was 10,268, which had dropped to 9,637 in 1919, to 6,438 in 1921, increased to 7,599 in 1929, and dropped to 6,257 in 1933.

The war exerted two influences upon the chemical industry which have had far-reaching effects. The first was the stimulus given to production of dyes in this country and the second was the holding up to manufacturers of the importance of research work in developing new products and in devising new processes for the production of old products.

The Bureau of the Census in a survey of the U. S. dye industry in 1914 reported that there were seven establishments in this country engaged in the manufacture of dyes. The 1914 output was 6,619,729 lb., with a value of $2,470,096. How this branch of the industry has grown is shown in the following tabulation.

Domestic Production of Dyes

	Lb.	Value
1914	6,619,729	$2,470,096
1917	45,977,246	57,796,228
1918	58,464,446	62,026,390
1919	63,402,194	67,598,855
1920	88,263,776	95,613,749
1921	39,008,690	39,283,956
1922	64,632,187	41,463,790
1923	93,667,524	47,223,161
1924	68,679,000	35,012,400
1925	86,345,438	37,468,332
1926	87,978,624	36,312,648
1927	95,167,905	38,532,795
1928	96,625,451	39,792,039
1929	111,421,505	45,842,130
1930	86,480,000	38,621,610
1931	83,526,000	38,564,000
1932	71,269,000	32,944,000
1933	100,952,778	43,102,469

Up to 1921 figures for values represent total production, from 1921 figures for values represent only the amounts for sale.

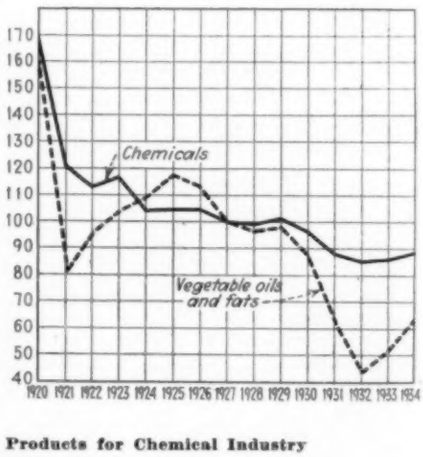
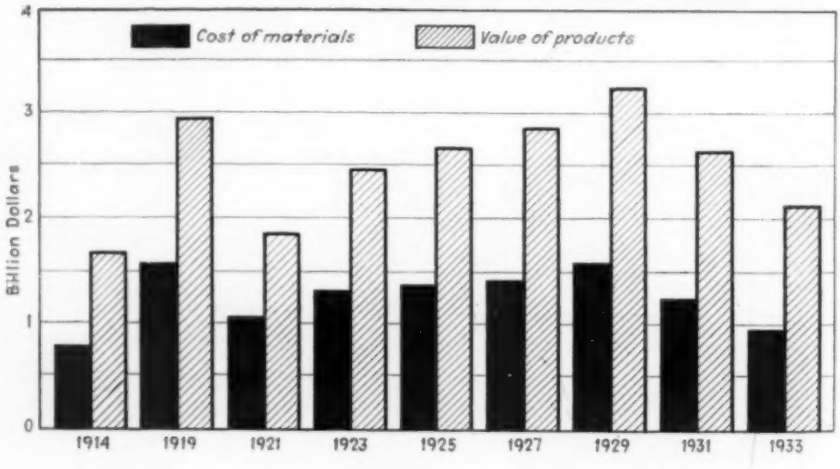
Synthetic organic chemicals have attained a prominence in recent years that makes only the most recent comparisons of any value. The 98 domestic firms manufacturing synthetic organic chemicals not derived from coal tar report a production of 771,574,595 lb. in 1933, or 27 per cent increase over 1930. Sales of 542,679,454 lb., valued at $55,604,615, represent an increase of 24 per cent in quantity and a decrease of 15 per cent in value as compared with 1930. Although 305 chemicals are included in this group, 31 of them account for seven-eighths of the total production.

Synthetic medicinals of non-coal-tar origin are listed separately for the first time in the report for 1933. The barbituric acid derivatives, an important class of products in this group, account for more than 50 per cent of the total sales value. Sales of these derivatives totaled 69,018 lb., valued at $555,757, in 1933, as compared with 18,932 lb., valued at $248,893, in 1930. During the same period the unit value of sales declined from $13.17 to $8.05 per lb.

Sales of synthetic resins not of coal-tar origin increased 82 per cent in quantity and 119 per cent in value over the preceding year.

Foreign trade in chemicals and allied products likewise has gone through various changes in recent years. Up to 1929, the balance of trade generally rested on the import side of the scale, but since then there has been a preponderance in favor of exports. A study of long time trends in the import field bears out the contention that home production of finished chemicals was making steady progress with a consequent decline in demand for foreign products. Arrivals from abroad were more restricted to raw materials, semi-manufactured products and finished products which, for various reasons, were able to offer price competition in domestic markets.

Price Trends for Chemicals and Oils



Cost of Materials and Value of Products for Chemical Industry